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## III.—VERTICAL FORMS OF CONTINENTS.

### I. General Relief Forms.

1. Relief Defined. The vertical configuration of a continent or island—that is, its elevation as a whole, varied by plains, table-lands, mountains, and valleys—is called its *relief.*

The elevation of any given point, reckoned from the level of the sea as a common base, is called its *altitude.* The height of a hill, mountain, or plateau, above the surrounding country, is its *relative elevation.*

2. Classes of Relief Forms. Although the forms of relief are exceedingly varied, they may all be referred to two great classes; namely, *elevations in mass*, and *linear elevations.*

*Elevations in mass*, or great areas of nearly uniform altitude, are called plains or lowlands, when their altitude is less than 1,000 feet; and plateaus or table-lands, when it reaches or exceeds 1,000 feet.

*Linear elevations* are those whose breadth is slight compared with their length. In this class are included chains of mountains and hills, and the intervening valleys. The term hills is applied to ridges less than 2,000 feet in elevation.

3. Importance of a Study of Relief Forms. The loftiest mountains, when compared with the diameter of the Earth, are but as grains of sand upon a globe several feet in diameter; yet the element of altitude so powerfully affects climate and organic life, that a knowledge of the reliefs of the several continents is of the utmost importance.

A difference in altitude of no more than 330 feet, is sufficient to produce a difference in temperature of 1° Fahrenheit, being equivalent to a difference of seventy miles in latitude. An increase in altitude of but a few thousand feet, therefore, changes entirely the character of a region, like a removal of it from torrid to temperate latitudes, or from temperate to frigid.

Again, the relief of a continent controls its *drainage*, shaping the river basins, and directing the course of its flowing waters; and influences, to a certain extent, the direction and character of the winds, and the distribution of rain.

### II. Plains.

1. Extent of Plains. Plains occupy nearly one-half of the surface of the continents. They are most extensive and unbroken on the Arctic slopes of the Old World, and in the interior of the two Americas.

The great *Siberian plain* extends from the northeastern extremity of Asia to the Ural Mountains and Caspian Sea; and the *European plain* stretches from the Ural westward, through Russia and North Germany, to the lowlands of Holland.

In *North America* the great central plain extends, with but slight interruptions, from the Arctic shores to the Gulf of Mexico.

In *South America* the plains of the Orinoco basin, the Selvas of the Amazon, and the Pampas of the La Plata, form an uninterrupted series of lowlands which, continued by the plains of Patagonia to the southern extremity of the continent, extend over a distance of 3,500 miles from north to south.

The interior of *Australia* is also a plain of great extent. The plains of China, Hindostan, and the Euphrates basin, in Asia, justly celebrated as the seats of mighty civilized nations, are smaller and of a more local character.

2. Surface. On account of differences in the character of their surface, plains may be divided into three general classes; namely, *alluvial*, *marine*, and *undulating* plains.

*Alluvial plains* are almost absolutely level, their surface often being unbroken by any elevation deserving even the name of a hill.

They are formed of materials deposited by rivers upon overflowed lands along their courses, or in shallow waters about their mouths, the deposits gradually converting the shallows into flat, moist lands.

The most marked examples of alluvial plains are the delta of the Mississippi and the flat bottom land, from thirty to eighty miles in width, lying between its bluffs; the great plains of the Amazon, the Orinoco, and the La Plata; the low plains of China, Hindostan, and the lower Euphrates; the delta and valley of the Nile; and the plains of the Po and of the lower Rhine.

*Marine plains* are so called because they seem to have been formed under sea-water, and resemble the sandy bottom of an ancient ocean.

They show but slight inequalities of surface, due to local accumulations of sand drifted by the currents, or to other accidental causes; and, where there is a scarcity of rain, the soil is frequently impregnated with salt, soda, and other substances remaining after the evaporation of sea-water.

Plains of this class are situated, chiefly, on the shores of the continents, or around great salt lakes and inland seas; like the sandy plains of our Atlantic slope, and those adjacent to the Baltic, the Caspian, and the Aral Sea.

*Undulating plains* have the surface varied by swells of greater or less elevation, but rarely much above the general level. They occupy an intermediate position between the highlands of the continents and the low alluvial and marine plains.

Of this class are the larger part of the plains in the Mississippi basin, and the uplands at the eastern foot of the Appalachian Mountains; the central and southern plains of Russia, and the eastern half of the Siberian plain.

3. The productiveness and general aspect of plains vary as widely as their surface.

*Treeless* plains, whose vegetation consists of grasses and other herbaceous plants, or stunted shrubs, occur in every continent, and are designated by a variety of terms.

In North America the fertile treeless plains are termed "*prairies*" (meadows), while the sterile ones, east of the Rocky Mountains, are known as "*the plains.*"

In South America the Spanish term "*llano*" (plain), and the Peruvian "*pampa,*" designate the treeless plains of the Orinoco and La Plata basins. Those of eastern Europe and Asia are denominated "*steppes;*" while more limited treeless regions in western Europe are called "*landes*" and "*heaths.*"

Wherever treeless plains are subject to periodical rains, they lose their verdure in the season of drought, and assume the aspect of a desert; but they resume their freshness on the return of the rain, and many are adorned with a great variety of beautiful flowers.

The *marine plains* being chiefly sandy, are the least fertile; but the more favored ones produce forests of pine and excellent pasturage; like the Baltic plains of Europe, and the sandy plains on the Atlantic coast of North America.

The plains of the Caspian Sea and western Siberia are dreary steppes, covered with coarse grasses, often growing in tufts, alternating with patches of heather, furze, dwarf birch, and other stunted shrubs; or old sea bottom, covered with salt eflores-

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# PHYSICAL

# GEOGRAPHY

BY

## ARNOLD GUYOT

**Gold-Medalist for Geography, Paris Exposition, 1878, and Author of "Guyot's Geographical Series," "Earth and Man," "Creation," etc.**

NEW YORK .:. CINCINNATI .:. CHICAGO
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# PREFACE.

Physical Geography, in the highest sense of the term, is the Science of the Earth as a great individual organization. In this science the material body of the globe, with its atmosphere, the myriads of plants and animal forms living upon it, and man himself, as a part of the life-system, are not only considered in themselves, but in their mutual relations, as working together towards a common end. Though entirely resting upon the solid basis of observed phenomena, it does not stop there. Its aim is pre-eminently the discovery of the laws which govern these phenomena, and of the grand chain of causes and effects which explains the mode of their occurrence.

Such a study requires an extensive knowledge of facts drawn from the domain of all the natural and physical sciences, which cannot be expected of the youthful student, and a habit of generalization which does not belong to the early stages of mental development. A full treatment of Physical Geography and its intricate problems is, therefore, more in place in the highest institutions of learning than in our general school system.

But by far the greater number of the youth in our schools will never enter the walls of a college or university. A glance, however, at the subjects treated in the present work, will convince every thoughtful mind that, in this age of universal education, it would be a grievous mistake to send this multitude into the wide world of active life, without some knowledge of the laws of these natural phenomena, in the midst of which we live and move.

The mariner on the stormy sea, the agriculturist at home, the merchant embracing the world in his commercial ventures, the far-seeing statesman — all have a direct interest in knowing the course of the winds, the laws of the distribution of heat and rains, which regulate the abundance or scarcity of crops, determine the special nature of the useful productions in every part of the inhabitable globe, and, in consequence, the resources and the intercourse of the civilized nations.

The problem to be solved in preparing the work was to furnish to the pupils of higher grades a general outline of Physical Geography which, by its simplicity and conciseness, would be suited both to the amount of general information they are expected to possess, and the limited time available for this study in the school course. This task the author has attempted to perform without sacrificing the special character of the science. All parts of the subject are presented in their true relations, as the writer conceives them, and in their proper subordination. They form a body of facts strongly connected together by ties of mutual dependence, which, once well understood and thoroughly mastered, in the spirit of the book, cannot fail to be easily and forever remembered, while, at the same time, they establish a sound basis for future progress.

In every part of the work a strict geographical point of view has been preserved. From the kindred sciences — geology, natural philosophy, meteorology — only such facts and principles have been borrowed as were necessary to illustrate geographical phenomena. In the exposition of the life-system the associations of plants, animals, and races of men in geographical groups, characterizing the great natural divisions of the globe, have been defined, and not the botanical, zoölogical, or ethnological classifications.

To enliven the presentation of the subject by vivid descriptions of remarkable phenomena, or countries, would have been a pleasant and easy task, but the prescribed space forbade any such indulgence. A text-book can be but little more than a skeleton designed to give solidity, and to put order and method in the structure to be erected. To the intelligent teacher belongs the privilege of clothing these dry bones with forms of life and beauty. But the teacher and the pupil will find an invaluable help in the analyses placed at the end of the sections, and it is hoped that the latter will be thus induced to perform that mental process without which a real acquisition of knowledge is simply impossible.

The numerous maps constitute in themselves a work as laborious as it is indispensable. They have been prepared with great care, and are thought to embody the results obtained to the present day in this domain of scientific inquiry. The illustrations have been selected strictly with a view to instruct the pupil, and not simply to adorn the pages of the volume; and the execution of the work gives ample evidence that the publishers have spared neither pains nor expense to do justice to the subject, and extend the usefulness of this manual.

This volume closes the series, now complete, of the geographical text-books which the author had engaged to prepare for our public schools. It represents the highest of the three normal stages of study, alluded to and fully defined in the preface of the lower books, and in the accompanying manual of geographical teaching. Experience has shown that, in the hands of the proper teacher, — and we ought not to have any others, — these manuals carry the pupil to the aim with ease, and by gradual and sure steps. It is a most gratifying fact that the method on which they are based has received the full indorsement of the best educators both in this country and abroad.

To those who, having used the first books of this series, have patiently waited for this work, the author begs to express his sincere regret that an unexpected interruption in his usual health, which rendered a prolonged absence necessary, should have retarded, for more than two years, the issue of this volume.

With this last offering the author takes leave of the youth of our schools, and their teachers, with an already well-grounded assurance that more than a half score of his best years, earnestly devoted to the introduction of a method of instruction more rational than that of mechanical memorizing, — which is still the bane of too many of our schools, and the strongest barrier to all progress, — have not been spent in vain for the cause of public education.

ARNOLD GUYOT,
*Blair Professor of Physical Geography and Geology, College of New Jersey.*

Princeton, New Jersey, *April* 25, 1873.

## NOTE TO THE REVISED EDITION.

In preparing new plates for this work, the publishers have taken occasion to make such corrections in the text as were rendered necessary by recent advances in geographical knowledge. The maps also have been newly engraved; and in their present form they not only represent the best skill of the engraver's art, but also embody the freshest data attainable in scientific research.

The work of revision has been done in pursuance of the plans of the lamented author, so far as these were known. Our acknowledgments are due to Professor William Libbey, jun., and Mr. Ernest Sandoz, of Princeton, N.J., both of whom were intimately associated with Dr. Guyot during many years of his most arduous scientific work.

IVISON, BLAKEMAN, TAYLOR, & COMPANY.

New York, Feb. 1, 1885.

# ANALYSIS OF THE VOLUME.

## PART I. — THE EARTH.

I. Introduction. Nature of Physical Geography. Subdivisions.
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III. The Earth in the Solar System.
IV. The Globe, — its Form, Volume, and Mass.
V. The Globe, — its Circles and Surface Measurements.
VI. The Globe as a Magnet.
VII. Temperature of the Globe, independently of the Sun's Rays.
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IX. Results Continued. Distribution and Cause of Volcanoes.
X. Results Continued. Earthquakes.
XI. Review of Part I.

## PART II. — THE LAND.

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III. Relief Forms Classified. Plains Described.
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VI. Structure of Asia.
VII. Structure of Europe.
VIII. Structure of Africa and Australia.
IX. General Laws of Continental Reliefs.
X. Islands classified. Formation of Coral and Volcanic Islands.
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## PART III. — THE WATERS.

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    2. Lakes, — their Formation and Distribution.
    3. Drainage of North America described.
    4. Drainage of South America.
    5. Drainage of Asia and Europe.
    6. Drainage of Africa and Australia.
III. The Sea.
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    2. The Oceans. Their Forms, Sizes, Depths, etc.
    3. Oceanic Movements. Waves and Tides.
    4. Marine Currents.
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## PART IV. — THE ATMOSPHERE.

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III. Physical Climate. Deviations from Astronomical Climate, Classification and Cause.
IV. The Winds. General Circulation of Atmosphere. Trade Winds.
V. Winds Continued. Periodical Winds. Variable Winds.
VI. Revolving Storms. Character and Cause.
VII. Distribution of Vapor in the Atmosphere.
VIII. Time and Character of Rains in Different Latitudes.
IX. Rainfall of the Different Continents.
X. Snow, Horizontal and Vertical Distribution.
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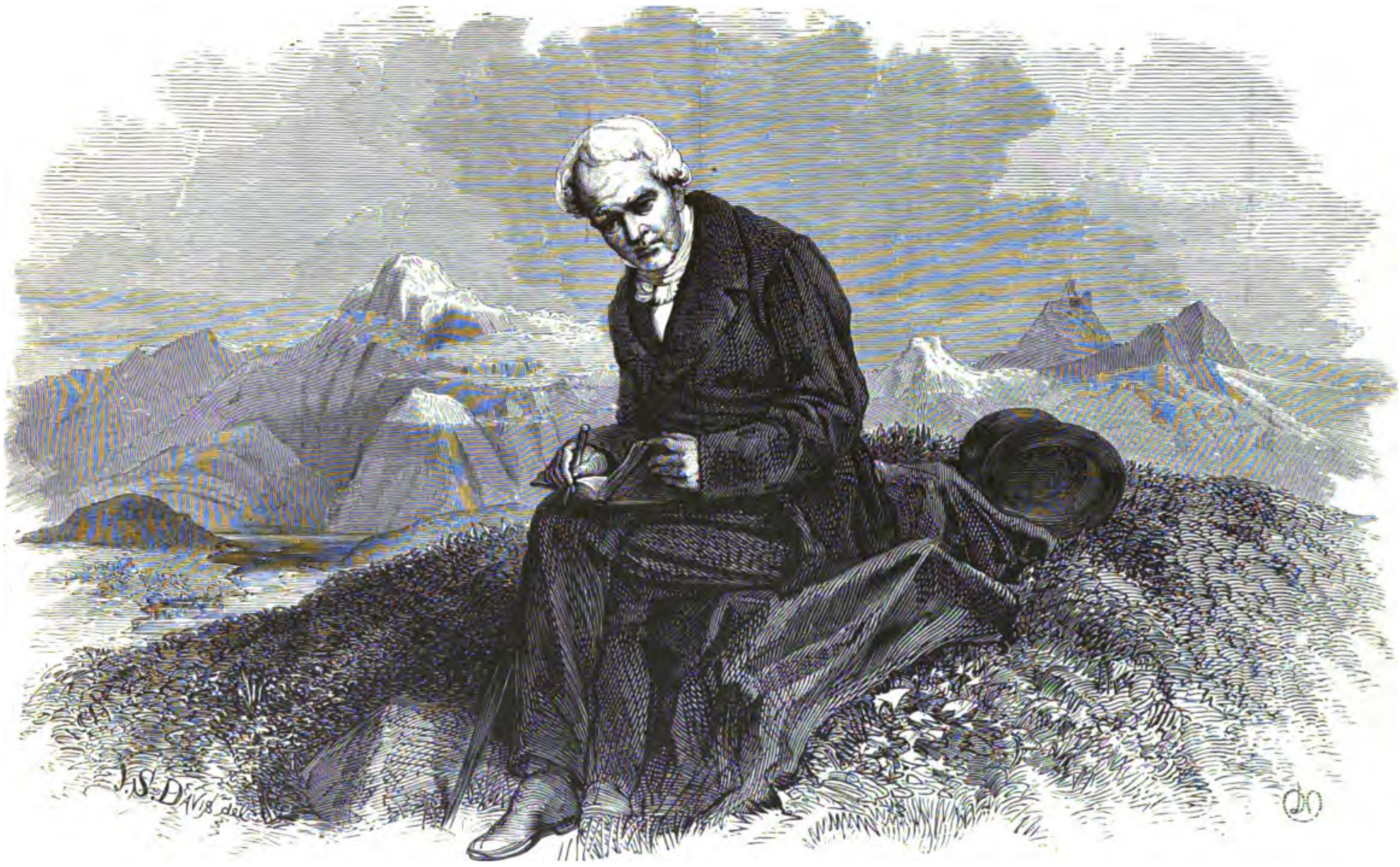
# PHYSICAL GEOGRAPHY.

## PART I.

## THE EARTH.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ALEXANDER VON HUMBOLDT.

*(From the portrait by Schrader, in possession of Albert Havemeyer, Esq., New York.)*

## I.—NATURE OF PHYSICAL GEOGRAPHY.

### I. Subject of Geographical Science.

THE EARTH, as an individual organization with a definite structure, character, and purpose, is the subject of geographical science. The *globe* as a whole, the three great geographical elements which it comprises,—the *land*, the *water*, and the *atmosphere*,—and the *organic life* which it supports, each presents peculiar classes of phenomena which it is the province of the scientific geographer to investigate, both in their individual character and their mutual relations.

### II. Points of View in which the Earth may be studied.

The EARTH, as the subject of geographical science, may be regarded in two different points of view:—

1. In ITSELF, as a master-piece of Divine workmanship, perfect in all its parts and conditions.

2. In ITS PURPOSE, as the abode of Man, the scene of his activity, and the means of his development.

The first gives rise to the *Geography of Nature*, the second to the *Geography of Man*.

### III. Geography of Nature.

The MODE OF TREATMENT in the geography of nature may be either simply descriptive, or scientific.

1. Descriptive natural geography, or Physiography,[1] is a simple description of the surface of the globe — of the position, extent and character of the lands; the distribution and extent of the waters; and the nature of the climate and productions in different parts of the Earth. It *forms the basis* of scientific geography.

2. Scientific natural geography, or Physical Geography proper, not only describes the various phenomena exhibited by the Earth as an individual organization, but seeks to discover the laws which govern them, and investigates their relations, causes, and consequences. This department of geography is frequently, and very properly, called *Terrestrial Physics.*[2]

### IV. Problems of Physical Geography.

Among the problems which physical geography aims to solve are the following: —

1. What *laws* govern the situation, extent, outlines, and relief[3] of the *land masses?*

2. What is the *influence of the relief* of the continents upon the formation of their systems of rivers and lakes?

3. What is the cause, the extent, the connection, and the influence of the great *oceanic currents?*

4. What is the fundamental law of the *distribution of heat* upon the surface of the globe; what modifications of this law are observable; and how are those modifications produced?

5. What general *atmospheric movements* have been observed, and what is their cause, course, and influence?

6. What laws control the *periods, distribution, and amount of rain* upon different portions of the globe; and how is the existence of vast rainless regions in certain latitudes to be accounted for?

7. What general laws govern the *distribution of vegetable and animal life* upon the globe, and how are these laws related to the character and well-being of the human family?

### V. Results of a Study of Physical Geography.

A careful study of physical geography tends to lead the mind to the conclusion that the *great geographical constituents of our planet* — the solid land, the ocean, and the atmosphere — *are mutually dependent and connected by incessant action and reaction* upon one another; and hence, that the Earth is really a wonderful mechanism, all parts of which work together harmoniously to accomplish the purpose assigned to it by an All-wise Creator.

### VI. Physical Geography distinguished from Geology.

1. Geology, sometimes wrongly included in physical geography, is the study of the Earth under quite another aspect. It describes, in their succession, the *past ages of the globe*, before the creation of man, and seeks to give a true history of the long periods of gradual formation by which it was made ready for the reception of mankind.

**Like all other bodies in nature, the Earth had its periods of slow, gradual formation, preceding its completed state. The rocks composing the solid mass of the land were long ages in forming; the continents emerged by slow successive steps from beneath the sea, system after system of mountains contributing to their final figure and relief; tribes of animals and plants, differing from existing species, appeared successively in vast numbers, during untold periods of time. These successive stages of progress form the materials for the science of geology.**

2. Physical Geography, on the contrary, concerns itself only with the present completed condition of the globe; thus it begins where geology ends. Its natural subdivisions are as follows: —

1. *The Earth as a whole.*
2. *The Land.*
3. *The Water.*
4. *The Atmosphere.*
5. *The Life upon the globe.*

### ANALYSIS OF SECTION I.

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**II. Points of View in Geographical Study.**
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  2. Influence of Relief on Drainage.
  3. Ocean Currents.
  4. Distribution of Heat.
  5. Atmospheric Currents.
  6. Laws of Rain-fall.
  7. Distribution of Life on Globe.

**V. Results of Geographical Study.**
  1. Geographical Constituents connected and mutually dependent.
  2. The Earth a Mechanism designed for a Definite Purpose.

**VI. Distinction between Geology and Physical Geography.**
  1. Geology studies Past Conditions.
  2. Physical Geography studies Present Conditions.
  3. Subdivision of Physical Geography.

## II. — THE EARTH IN THE UNIVERSE.

### I. The Universe.

The Universe is a general term used to represent the entire material creation. *Our knowledge* of it, however, is confined to a partial acquaintance with the Earth and its sister planets, and some general ideas in regard to the more distant heavenly bodies, whose existence is revealed to us only by the light they shed upon the earth.

### II. The Starry Heavens.

1. The Heavenly Bodies, which occupy the immensity of space, appear to be arranged in groups, or systems, sweeping through immeasurable circuits.

Our *Sun* is the self-luminous centre of a group of small non-luminous bodies called *Planets*,[4] which reflect his light, and, revolving around him, accompany him through space. Our *Earth* is one of these planets. These solid bodies, together with a few apparently gaseous and partially self-luminous bodies called *Comets*, form the *Solar System.*

The *fixed stars*, which adorn the heavens in countless numbers, are suns, — many of them of vastly greater magnitude than our Sun, — some revolving around one another, while others, possibly, are the centres of planetary systems like ours. They are at such vast distances from us that their light alone is within the reach of our observation.

---

[1] From two Greek words, ***phusis***, nature, and ***grapho***, to write.

[2] From the Greek ***phusikos***, pertaining to nature. ***Terrestrial***, belonging to the Earth.

[3] Elevation of the surface.

[4] Planet, from the Greek ***planao***, to wander.

2. The MAGNITUDE OF THE STARRY HEAVEN is such that our entire solar system, extending over an area 5,550 millions of miles in diameter, is only a point in the boundless space.

A ray of light from the Sun, travelling 185,600 miles in a second of time, reaches Neptune, the most distant known planet, in a little more than four hours; but it requires more than three years to reach the *nearest fixed star*, and three years more to reach the next. It may travel on, from system to system, for *two or three thousand years* before reaching the limits of the starry heavens visible to the naked-eye.

### III. Nebulæ.

Separated from our starry heavens by empty abysses of inconceivable magnitude, are other heavenly bodies called *nebulæ*, of which more than 6,000 have been observed.

Some of these, seen through the most powerful telescopes yet produced, appear only as small shining clouds, whence their name.[1] Others have been found to be composed of multitudes of stars, apparently clustered together, but doubtless as widely separated as the stars above us. Thus there may be other starry heavens, possibly yet more extensive than that which gladdens our eyes.

### IV. Insignificance of the Earth.

The *Earth*, therefore, vast as it seems to the feeble mind of man, is only one of the smaller members of a little family of planets. The *Sun*, the all-controlling centre of this family, with a multitude of other suns, forms one group of stars in the immensity of the visible heavens; while the measureless firmament itself is filled with myriads of star clusters, which "declare the glory of God" and "show forth his handiwork."

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- 1. SIGNIFICANCE OF TERM.
- 2. EXTENT OF OUR KNOWLEDGE OF IT.

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    - Planets.
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  - a. Extent of Solar System.
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**III. Nebulæ.**
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- 2. THEIR NUMBER.
- 3. THEIR APPEARANCE.
- 4. THEIR PROBABLE CHARACTER.

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- 1. THE EARTH IN SOLAR SYSTEM.
- 2. SOLAR SYSTEM IN SUN GROUP.
- 3. SUN GROUPS IN VISIBLE HEAVENS.
- 4. STAR CLUSTERS IN FIRMAMENT.

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[1] From the Latin *nebula*, a little cloud.

## III. — THE EARTH IN THE SOLAR SYSTEM.

### I. Bodies composing the Solar System.

The Solar System consists of the *Sun*, — the central and controlling body, — eight *primary planets*, and twenty secondary planets or *satellites* revolving around their several primaries; more than one hundred and twenty *asteroids*,[2] which are small planets visible only through the telescope; and an indefinite number of comets.

The primary planets are separated by the asteroids into two groups of four each, one between the asteroids and the Sun, the other beyond them. Recent observations render probable the existence of another planet between the Sun and Mercury.

### II. Primary Planets.

1. RELATIVE POSITION. The primary planets, in the order of their position, are Mercury, — the nearest to the Sun, — Venus, the Earth, and Mars composing the first group; Jupiter, Saturn, Uranus, and Neptune composing the second.

2. COMPARATIVE SIZE. The size of the planets, in general, increases with their distance from the Sun. The four composing the *first group* are all comparatively small, the Earth being the largest. Those of the *second group* are all of great size. Jupiter, the largest, is not less than 1,390 times as large as the Earth; but as it is much less dense, the amount of matter it contains is only a trifle more than 337 times that of the Earth. All the planets together equal but $\frac{1}{700}$ part of the mass of the Sun.

3. COMPARATIVE DENSITY. The density of the planets decreases with their distance from the Sun. Mercury, the most dense, has a specific gravity[3] of $8\frac{1}{2}$, a little greater than that of iron; the Earth, $5\frac{2}{3}$; and Venus and Mars about the same; Jupiter, $1\frac{1}{3}$; and Saturn, the least dense of all the planets, but $\frac{7}{8}$, or about the same as cork.

4. The DISTANCE BETWEEN THE PRIMARY PLANETS increases with their increasing distance from the Sun. Reckoning the asteroids as one place, and excepting Neptune, the distances of the successive orbits from the orbit of Mercury increase in very nearly a twofold ratio. Thus from Mercury to Venus is 31 millions of miles; to the Earth, 56 millions; to Mars, 105 millions, etc.

The four smaller planets are all comparatively near the Sun, their several distances from it being only 36, 67, 92, and 141 millions of miles; while Jupiter, the nearest of the great planets, is 481 millions of miles distant. Neptune, the most distant, is 2,775 millions of miles away.

5. The SATELLITES, except our moon, and the two satellites of Mars, belong wholly to the second group of planets. Jupiter has four; Saturn eight, and several revolving rings; Uranus has four, and possibly more; while Neptune, so far as known with certainty, has but one.

### III. Movements within the Solar System.

1. ROTARY MOTION. The Sun, all the primary planets, and their satellites, as far as known, rotate from west to east. Each rotation constitutes a day for the rotating body. The central line of rotary motion is called the *axis* of rotation, and the extremities of the axis are called the *Poles*.

2. REVOLUTION AROUND THE SUN. All the *primary planets* and *asteroids* revolve around the Sun in the direction of their rotation, that is from west to east; and the planes[4] of the

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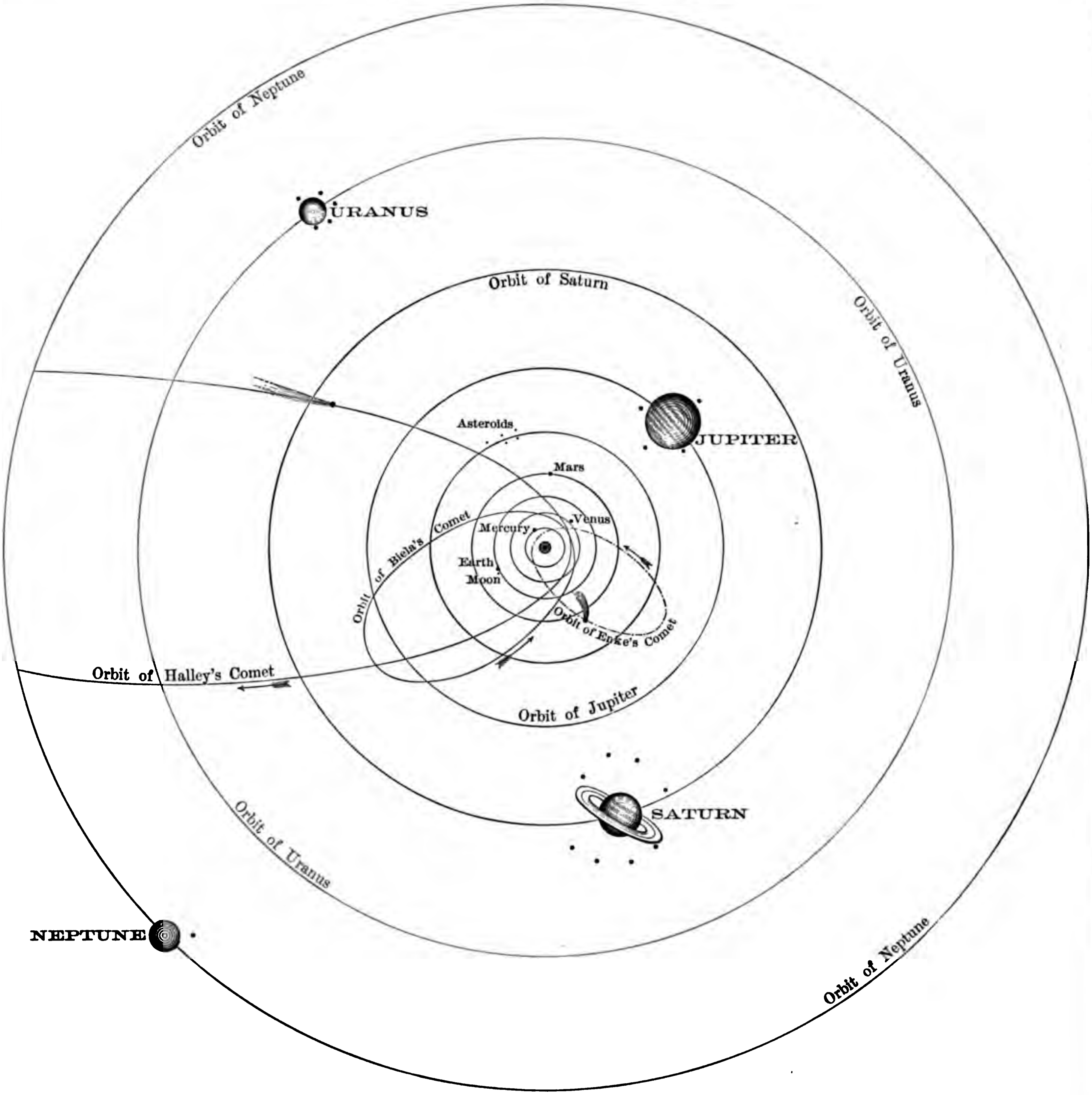
[2] These may be fragments of a former great planet occupying the same place in the system.

[3] Weight as compared with an equal bulk of pure water.

[4] The ideal plane in which their circular path is conceived to lie.

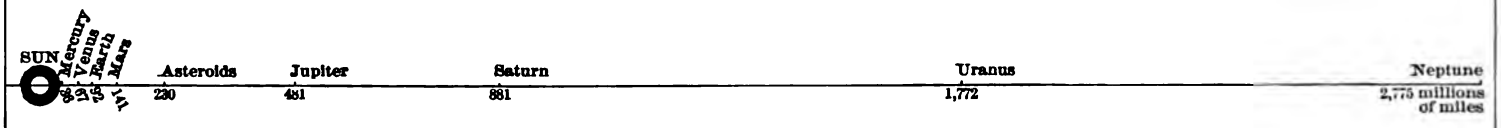
# THE SOLAR SYSTEM.



IN THE ABOVE DIAGRAM

**THE RELATIVE SIZES OF THE SUN AND PLANETS ARE PRESERVED,**

**THE SIZE OF THE SUN BEING REPRESENTED BY THE ORBIT OF NEPTUNE.**



**COMPARATIVE DISTANCES OF THE PLANETS FROM THE SUN.**

orbits in which they revolve coincide very nearly with the plane of the Sun's equator.[1] One revolution around the Sun constitutes the *year* of a planet.

All the *satellites*, except those of Uranus and perhaps Neptune, also revolve from west to east.

**Most of the comets revolve around the Sun in very irregular and elongated orbits, only a few having their entire orbit within the planetary system. Some so move that after having entered our system and made their circuit around the Sun, they seem to leave it, never to return.**

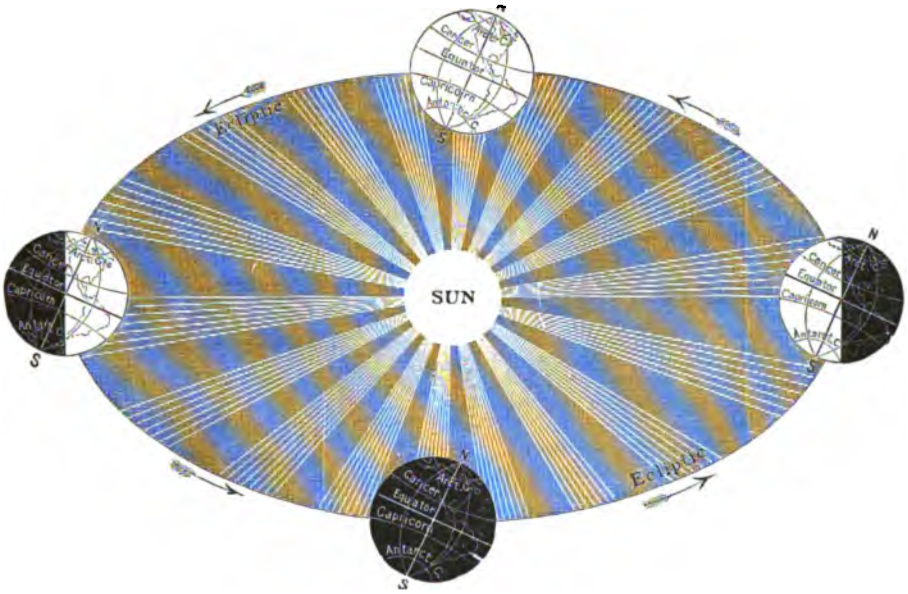
3. VELOCITY OF PLANETARY MOVEMENTS. The *velocity* of the planets in their *annual revolutions* decreases as their distance from the Sun increases. Mercury moves at the rate of nearly 2½ millions of miles per day, and the Earth 1½ millions; while Neptune advances at the slower pace of little more than ¼ of a million.

The *velocity of rotation*, on the contrary, is least in the smaller planets which are near the Sun, while it is greatest in the larger and more distant ones. The former require from 23½ to 24½ hours of our time for one rotation; while the latter, except Neptune, whose rotary velocity is not known, accomplish an entire rotation in from 9½ to 10½ hours.

4. TIME OF REVOLUTION. As the orbits of the planets increase in circumference with their distance from the Sun, and their velocity at the same time diminishes, the time of revolution, or *length of the year*, increases correspondingly. Mercury performs a revolution in about 88 days of our time; and the Earth, in 365¼; while Jupiter requires 4,332, and Neptune 60,126 days.

5. The AXES of all the planets, so far as known, are more or less inclined towards the planes of their orbits. This *inclination causes* an apparent passing of the Sun from one hemisphere to the other during the course of the annual revolution, thereby producing variation in the relative length of day and night, and change of seasons. The *greater the inclination* of the axis, the greater is the variation in the length of day and night, and the more extreme the contrasts in temperature during the year at any given point.

The *Earth* seems to present a happy medium in this respect. Its axis is inclined about 23½°,[2] sufficient to give the larger part of its surface four seasons of nearly equal length, — Summer, Winter, and two transition seasons of medium temperature, — with day and night varying from 9 or 10, to 14 or 15 hours; while but a small area, extending 23½ degrees from each pole, is ever entirely deprived of the Sun's rays during one or more rotations of the Earth. The two polar regions combined occupy but 16½ millions of square miles, out of 197 millions, the entire surface of the Earth.



THE ORBIT OF THE EARTH.

**If the axis of the planet *Venus* be, as is supposed, inclined 72°, then in the course of its annual revolution the Sun must be vertical on every part of its surface except a little area extending 15° from the poles, where it is so nearly vertical as to produce scarcely less heat than if it were so. Thus every part of its surface must alternate between excessive heat during one half the year, and intense cold, from an almost entire absence of the Sun's rays, during the other half.**

6. ECCENTRICITY OF PLANETARY ORBITS. The planetary orbits are not exact circles, but are more or less elliptical, the Sun being situated not at the centre, but at one of the foci of the ellipse. The distance of either focus from the centre is called the *eccentricity* of the ellipse. On account of this eccentricity the distance of a planet from the Sun, and its velocity of revolution, vary in different parts of its orbit.

Some of the planets are so much nearer the Sun in one portion of their orbit than in another, that the degree of heat received varies greatly in different seasons of the year. Thus Mercury receives, when nearest the Sun, about 2¼ times as much heat as when most distant from it, a difference equal to the variation in temperature between summer and winter in the middle latitudes of our globe.

The *Earth*, on the contrary, revolves in an orbit but slightly eccentric. Its nearest approach to the Sun occurs in the winter of the northern hemisphere, where the larger part of the land is concentrated. Hence, if this slight eccentricity of the orbit has any appreciable effect upon climate, it must be to moderate the cold of winter, and the heat of summer, in the most populous zone of the globe.

## IV. Advantages in Conditions of the Earth.

The Earth is thus subject to physical conditions intermediate between the extremes presented by the other planets.

It is the largest of the smaller planets, and occupies a middle position in the group. This frees it alike from the blinding glare and burning heat to which Mercury is exposed, and the dimness of light and the cold which must prevail on distant Jupiter and Neptune.

The comparative *velocities* of its diurnal and annual *motions*, the trifling *eccentricity of its orbit*, and the slight *inclination of its axis*, establish a harmony in the relative length of its days, years, and seasons, and its alternations of temperature and of light and darkness, such as cannot exist in most of the other planets.

Thus the Earth appears better fitted than any other member of the solar system for sustaining that great wealth of organic life — vegetable, animal, and human — with which it is endowed, and which constitutes its greatest glory. Indeed, whatever may have been the past, or may be the future of the other planets, it is doubtful whether, at the present time, any one of them possesses those physical conditions under which alone a life-system at all similar to ours is possible.

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[1] A great circle, the plane of which cuts the axis of rotation at right angles.

[2] In more exact terms, 23° 28′.

### ANALYSIS OF SECTION III.

**I. Bodies Composing the Solar System.**
- 1. Sun, its Rank.
- 2. Primary Planets, their Number.
- 3. Satellites, Number and Relation to Primaries.
- 4. Asteroids, Number and Size.
- 5. Comets.
- 6. Grouping of Planets.

**II. Primary Planets.**
- 1. Relative Position.
- 2. Comparative Size.
  - a. Law of increase.
  - b. Size of first group.
  - c. Size of second group.
  - d. Total mass compared with Sun.
- 3. Comparative Density.
  - a. Law of decrease.
  - b. Specific gravity of small planets.
  - c. Specific gravity of Jupiter and Saturn.
- 4. Planetary Distances.
  - a. Law of increase.
  - b. Distance of small planets from Sun.
  - c. Distance of great planets from Sun.
- 5. Satellites.
  - a. To which group belonging.
  - b. Number accompanying each great planet.

**III. Movements within Solar System.**
- 1. Rotary Motion.
  - a. Direction.
  - b. Resulting measure of time.
  - c. Centre.
- 2. Revolution around the Sun.
  - a. Direction of motion.
    - Primary planets.
    - Asteroids.
    - Satellites.
  - b. Measure of time.
  - c. Revolution of comets.
- 3. Velocities of Planetary Motions.
  - a. Law of variation in revolution. Examples.
  - b. Law of variation in rotation. Examples.
- 4. Time of Revolution.
  - a. Law of variation. Example.
- 5. Axis of Rotation.
  - a. Law of position.
  - b. General effect of inclination.
  - c. Earth, degree of inclination. Results.
  - d. Venus. Supposed degree of inclination. Results.
- 6. Eccentricity of Orbits. Definition.
  - a. Mercury, Comparative Eccentricity. Results.
  - b. Earth, Comparative Eccentricity. Results.

**IV. Advantages in Physical Condition of Earth.**
- 1. Of Position in Solar System.
- 2. Of Velocity of Motions, Eccentricity of Orbit, and Inclination of Axis.

## IV.—THE TERRESTRIAL GLOBE.

### ITS FORM; VOLUME; MASS.

### I. Form of the Earth.

1. The Earth, as ascertained by mathematical measurements, is an oblate spheroid, being slightly compressed about the poles, and slightly bulging in the equatorial regions. The difference between the polar and the equatorial radius is only 13¼ miles.

2. This DEVIATION from a perfectly spherical figure is such as would be *produced* by the rotation of a slightly plastic[1] globe upon its axis. It indicates that the Earth, in some period of its existence, must have been in a semi-fluid condition.

### II. Volume or Bulk of the Terrestrial Globe.

1. The term volume, as applied to the Earth, signifies its size or dimensions, as shown by measurements, irrespective of the amount of matter contained in it.

2. The DIMENSIONS of the Earth, according to Herschel are:—

| | | |
|---|---|---|
| Equatorial diameter . . . | 7,925.65 | miles. |
| Polar " . . . | 7,899.17 | " |
| Mean " . . . | 7,916 | " |
| Circumference at equator . | 24,899 | " |
| Extent of surface . . . | 196,900,278 | square miles. |
| Solid contents . . . | 260,000,000,000 | cubic miles. |

3. The APPROXIMATE DIMENSIONS, expressed in round numbers for convenience in remembering them, are—diameter, 8,000 miles; circumference, 25,000 miles; extent of surface, 197 millions of square miles; solid contents, 260 thousand millions of cubic miles.

### III. Mass of the Globe.

1. The term mass, as applied to the Earth, signifies the amount of matter it contains irrespective of its volume.

*Material substances* differ greatly in the mass of matter contained in a given volume. Thus a cubic foot of stone weighs 2½ times as much as a cubic foot of water, that is, contains 2½ times as much matter; in other words, its specific gravity is 2½. The specific gravity of iron is 7½, that of lead 11½, of gold 19.

2. The SPECIFIC GRAVITY of the terrestrial globe is found to be about 5⅔; that is, it would require 5⅔ globes of water, of the same size, to balance the weight of the Earth.

3. The MATTER COMPOSING THE SURFACE of the globe is much less dense, having a specific gravity of but 2½; consequently the interior must be correspondingly denser. Hence we conclude, either that metallic substances predominate in the interior of the globe, or that the matter therein is very greatly compressed.

4. The ABSOLUTE WEIGHT of the globe is computed at not less than 5,852,000,000,000,000,000,000 of tons, a weight of which our minds can form no conception.

### ANALYSIS OF SECTION IV.

**I. Form of the Earth.**
- 1. Figure of the Earth.
- 2. Deviation from Perfect Sphere.
  - a. How produced.
  - b. Proves what.

**II. Volume of Terrestrial Globe.**
- 1. Signification of term Volume.
- 2. Exact Dimensions of Globe.
  - a. Equatorial Diameter.
  - b. Polar Diameter.
  - c. Mean Diameter.
  - d. Equatorial Circumference.
  - e. Extent of Surface.
  - f. Solid Contents.
- 3. Approximate Dimensions.
  - a. Diameter.
  - b. Circumference.
  - c. Surface and solid contents.

**III. Mass of Terrestrial Globe.**
- 1. Signification of term Mass.
  - Examples.
- 2. Specific Gravity of Globe.
- 3. Specific Gravity of Surface Regions. Conclusion.
- 4. Absolute Weight of Globe.

## V.—THE TERRESTRIAL GLOBE.

### ITS CIRCLES, AND SURFACE MEASUREMENTS.

### I. Circles of Position.

1. The term Circle, in geographical science, is used in a special sense. The *geographical circles* are not plains cutting the terres-

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[1] Capable of being moulded or shaped.

trial globe, but simply lines encircling it. Those which bisect the surface of the sphere are called *great circles;* all others, *small circles.*

2. Great Circles. The *Equator* is a great circle encompassing the globe from east to west, midway between the poles. *Meridians* are great circles encompassing the globe from north to south, intersecting at the poles, and crossing the equator at right angles.

3. The Parallels are small circles parallel to the equator.

4. Use. The parallels and meridians, which are conceived as intersecting at every point on the Earth's surface, are employed in determining the geographical position of places.

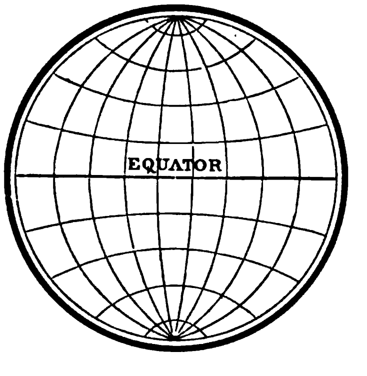
## II. Climatic Circles.

1. Climatic Parallels. Four parallels serve not only to determine position, but also to mark certain important climatic boundaries, hence they may be distinguished as climatic parallels.

The *Tropics*, situated 23½° from the equator, mark the highest latitude which receives the vertical rays of the Sun. Their position is fixed by the inclination of the Earth's axis 23½ degrees towards the plane of its orbit.

On the 21st of June the vertical Sun, in its diurnal course, passes over every point on the northern tropic; on the 22d of December, over every point on the southern. Twice in the year it passes, in succession, over every parallel between the tropics; from June to December advancing southward, from December to June, northward. (See page 70, *Positions of the Vertical Sun.*)

The *Polar Circles*, situated 23½° from the poles, mark the limits of illumination when the Sun is vertical at the tropics. Each is 90° distant from the tropic on the opposite side of the equator.



MERIDIANS AND PARALLELS.

2. The Ecliptic is a great circle whose plane coincides with that of the Earth's orbit, and consequently intersects the plane of the equator at an angle of 23½°. It marks the apparent path of the vertical Sun from tropic to tropic during the annual revolution of the Earth. The ecliptic bisects the equator, and touches the two tropics in opposite latitudes, and on opposite meridians.

## III. Surface Measurements.

1. Latitude is the distance of a place from the equator, measured upon the meridians. It is reckoned from the equator to each pole; hence there are 90° of north latitude and 90° of south latitude.

The *length of a degree of latitude* is 69$\frac{1}{6}$ miles, or $\frac{1}{360}$ part of the circumference of the Earth. Near the poles the degrees are slightly longer, owing to the oblateness of the sphere.

2. Longitude is the distance of a place east or west from some given meridian, called the *prime meridian*, measured on the equator. It is reckoned half way round the globe in each direction; thus there are 180° of east longitude and 180° of west longitude.

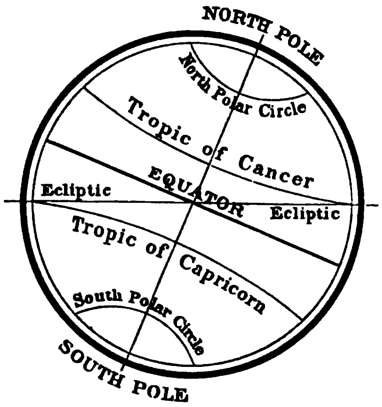
The *length of a degree* of longitude at the equator is 69$\frac{1}{6}$ miles. As the parallels constantly diminish in circumference from the equator to the poles, the length of a degree of longitude — $\frac{1}{360}$ part of each parallel — must decrease in like manner. At the poles, where all the meridians meet, longitude ceases. One minute of longitude at the equator constitutes the *geographical* or *nautical mile* used in reckoning distances at sea.

TABLE SHOWING THE CIRCUMFERENCE OF EVERY FIFTH PARALLEL, AND THE LENGTH OF ITS DEGREES IN ENGLISH MILES.

| Latitude. | Circumference of Parallel. | Length of degree of Longitude. | Latitude. | Circumference of Parallel. | Length of degree of Longitude. |
|---|---|---|---|---|---|
| Equator 0° | 24,899 | 69.164 | 45° | 17,636 | 48.988 |
| 5 | 24,805 | 68.902 | 50 | 16,036 | 44.545 |
| 10 | 24,523 | 68.120 | 55 | 14,314 | 39.760 |
| 15 | 24,056 | 66.822 | 60 | 12,481 | 34.669 |
| 20 | 23,406 | 65.018 | 65 | 10,552 | 29.310 |
| 25 | 22,580 | 62.721 | 70 | 8,541 | 23.726 |
| 30 | 21,581 | 59.948 | 75 | 6,465 | 17.957 |
| 35 | 20,418 | 56.718 | 80 | 4,338 | 12.049 |
| 40 | 19,100 | 53.055 | 85 | 2,177 | 6.048 |
| 45 | 17,636 | 48.988 | Pole 90 | 0,000 | 0.000 |

The *prime meridian* commonly employed by the English and the Americans, is that of the National Observatory at Greenwich, near London. The French and German geographers also use the meridian of the observatory at Paris, and the Americans often employ that of the National Observatory at Washington.[1]

The meridian of 20° west from Paris, falling somewhat beyond Ferro, the most westerly of the Canary Islands, is also employed as prime meridian; and, lying at the west of all the lands of the Old World, it has been generally adopted as the most appropriate boundary between the eastern and the western hemisphere.



CLIMATIC CIRCLES.

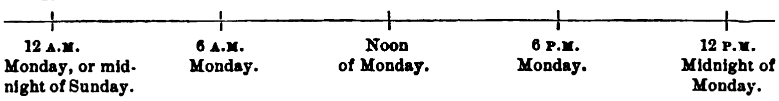
## IV. Relation of Longitude to Time.

1. Computation of Longitude by Time. Since any given point on the Earth's surface passes through 360° of longitude — one entire rotation — in 24 hours, it must pass through $\frac{360}{24}$°, or 15°, in one hour; and 1° in $\frac{1}{15}$ of one hour, or 4 minutes. Hence if the *difference in time* marked at two places be known, their difference in longitude can at once be ascertained, and *vice versa.*

Suppose, for example, an accurate time-keeper, marking New-York time, be taken to London: it will be found four hours and fifty-six minutes, or 296 minutes, slower than London time. Hence the difference in longitude, expressed in degrees, must be one-fourth this number, or $\frac{296}{4} = 74$°.

2. Difference of Time marked at the same Moment. The moment at which the Sun crosses the meridian of a given place, is *noon* or mid-day at that place. The meridian which is 90°, or a quarter of a rotation, to the eastward has six hours later time at the same moment; and one which is 180° east, twelve hours later. Meridians at corresponding distances to the westward have a corresponding number of hours earlier time; so, in proportion, of less distances.

The diagram below illustrates the different time marked in different longitudes at the same moment: —



Thus it happens that mariners, starting from a given point and sailing around the world to the west, *lose a day* in making the circumnavigation; while in sailing eastward they *gain a day*. To *correct this error*, in the former case they must, at some point, add one day to their reckoning of time, making the date 24 hours later, and in the latter case drop a day.

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[1] The International Meridian Conference which met in Washington in October, 1884, recommended the adoption of the meridian of the Greenwich Observatory as the *prime meridian* for all nations.

## ANALYSIS OF SECTION V.

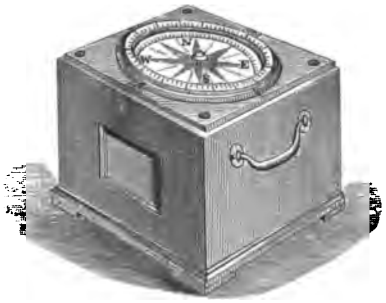
- **I. Circles of Position.**
  - 1. GEOGRAPHICAL USE OF THE TERM CIRCLE.
  - 2. GREAT CIRCLES.
    - a. Equator.
    - b. Meridians.
  - 3. PARALLELS.
  - 4. USE.
- **II. Climatic Circles.**
  - 1. PARALLELS.
    - a. Tropics. { Definition of. Position to what due.
    - b. Polar Circles. { Definition of. Position in reference to tropics.
  - 2. ECLIPTIC.
    - a. Definition.
    - b. What it marks.
    - c. Relation to tropics and equator.
- **III. Surface Measurements.**
  - 1. LATITUDE.
    - a. Definition.
    - b. Number of degrees.
    - c. Length of degrees. Exception.
  - 2. LONGITUDE.
    - a. Definition.
    - b. Number of degrees.
    - c. Length of degrees at the equator. How varying.
    - d. Prime meridians. { Locations of. Relative situation.
- **IV. Relation of Longitude to Time.**
  - 1. COMPUTATION OF LONGITUDE FROM DIFFERENCE OF TIME.
    - a. Basis of computation.
    - b. To convert difference of time to difference of longitude.
    - c. To convert difference of longitude to difference of time.
  - 2. DIFFERENCES OF TIME MARKED AT SAME MOMENT.
    - a. Variation eastward.
    - b. Variation westward.
    - c. Variations in circumnavigating the globe. How corrected.

## VI. — THE TERRESTRIAL GLOBE A MAGNET.

### I. Magnetism.

1. A MAGNET is a body which has the property of attracting iron; and the term MAGNETISM is applied to the cause of this attraction and the resulting phenomena. Magnetism was known to the ancients, having been *first observed* in the *loadstone*, a species of iron ore found in abundance near the city of Magnesia, in Asia Minor, whence the magnet takes its name.

2. ARTIFICIAL MAGNETS may be readily produced by friction. A bar of steel rubbed with a natural, or other, magnet acquires permanent magnetic properties. The magnetic needle is an artificial magnet suspended upon a pivot, so as to move freely in any direction. The Chinese availed themselves of it, in traversing the trackless deserts of central Asia, long before the use of the compass was known in Europe.

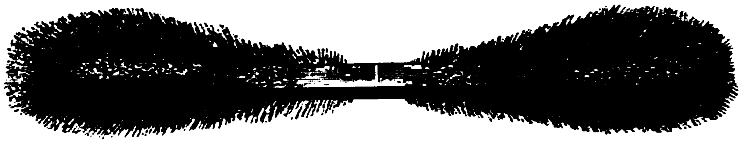

MARINER'S COMPASS.

The *mariner's compass* is a magnetic needle attached to the lower side of a leaf of mica, on which is traced a star with 32 points, marking the eight rhumbs, the semi-rhumbs, and the quarters of the wind. The compass is suspended in a box so as to preserve a horizontal position in spite of the motion of the ship.

### II. Properties of Magnets.

1. The MAGNETIC FORCE is not equally distributed throughout the magnet, but is greatest at the extremities, diminishing towards the centre, where it ceases. Every magnet, therefore, has two poles, at opposite extremities, — one *positive*, the other *negative*, — with a neutral line in the centre. They are distinguished as the *north pole* and the *south pole*. Poles of the same name repel, and those of contrary name attract each other. When a magnet is broken, each half becomes itself a complete magnet.

The illustration below represents a magnet which has been plunged into a basin of iron filings. These cluster in great numbers around the ends, each piece in contact with the magnet attracting others; but they are absent from the centre, where the opposite poles neutralize each other.


A MAGNET.

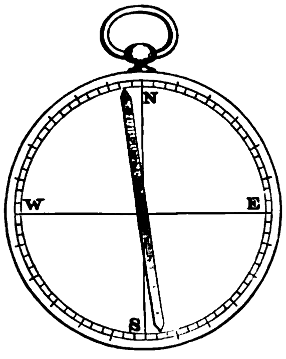
2. THE EARTH A MAGNET. The terrestrial globe exhibits the properties of a magnet in the *directing power* it exerts upon the magnetic needle. Whether on sea or land, on mountains or in deep valleys, a magnetic needle, if free to move, always so adjusts itself that its poles point in a definite direction, along a line which is virtually north and south.

That pole of the needle which is attracted by the north magnetic pole of the Earth, must be in an opposite magnetic condition. Hence it is the proper south pole of the magnet, but since it points toward the geographical north, it is designated the north pole.

3. The MAGNETIC POLES OF THE EARTH do not coincide with the poles of rotation, but are found about 20° from them. Neither do the magnetic meridians, which pass through the magnetic poles of the Earth and those of the needle, generally coincide with the geographical meridians, for the needle rarely points due north.

### III. Magnetic Variation or Declination.

1. MAGNETIC VARIATION, or declination, is the difference between the true north and the direction indicated by the magnetic needle. The declination is said to be *east* or *west*, according as the north pole of the needle is east or west of the geographical meridian.



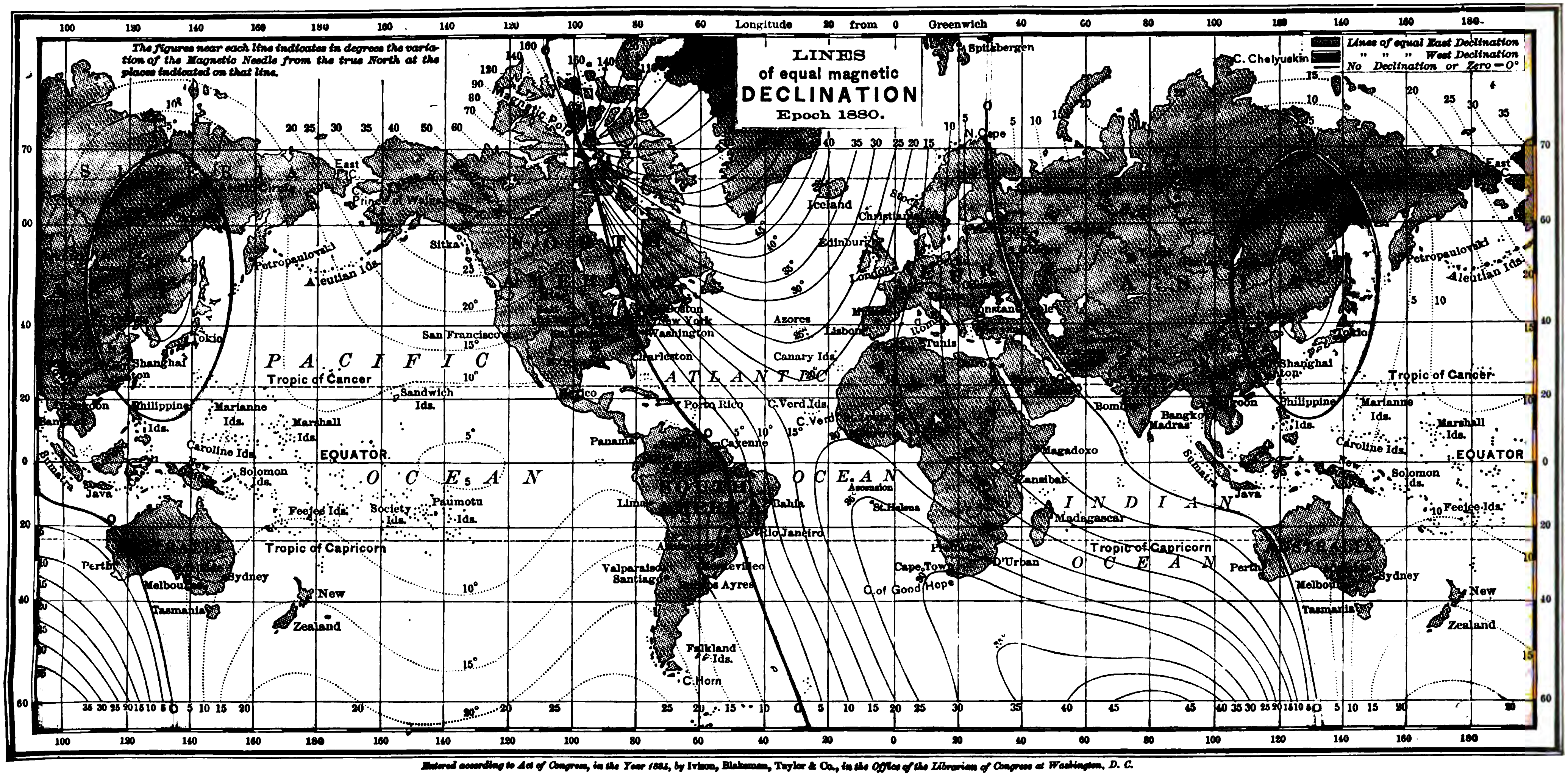
POCKET COMPASS.

By connecting all points which have equal declination, we obtain a system of lines which shows at a glance, as in the map on page 9, the extent to which the needle deviates from the true north, in all parts of the world. The eastern declination is distinguished on this map by dotted lines and a light brown color; the western by solid lines in a blue ground. The degree of variation is shown by figures attached to the lines.

The *lines of equal declination*, at all points on any one of which the needle preserves one unvarying direction, must not be confounded with *magnetic meridians* which, passing through the poles of the needle, would show what that direction actually is.

In certain parts of the globe the magnetic and geographical meridians coincide. These places are connected by an irregularly curved line called the *line of no variation*. One such line lies in the eastern, another in the western, hemisphere.

The *eastern* passes through the western portion of Australia, near the west coast of India, and across the Caspian and White


LINES
of equal magnetic
DECLINATION
Epoch 1880.
The figures near each line indicates in degrees the variation of the Magnetic Needle from the true North at the places indicated on that line.
Lines of equal East Declination
" " " West Declination
No Declination or Zero = 0°
Longitude from 0 Greenwich
PACIFIC OCEAN
ATLANTIC OCEAN
INDIAN OCEAN
EQUATOR
Tropic of Cancer
Tropic of Capricorn
Magnetic Pole

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seas. The *western* passes over Rio Janeiro and the mouth of the Amazon River; near the Lesser Antilles; and over Washington, Lake Huron, and Hudson Bay, to the north magnetic pole, in Boothia Felix, latitude 70° north. (See map above.)

Throughout the Africo-European and Atlantic hemisphere, the declination is west; on the Asiatic and Pacific hemisphere it is east, with the exception of a region in Eastern Asia, where an abnormal variation of the needle seems to indicate the existence of a secondary magnetic pole.

The position of the south magnetic pole is not positively determined.

2. SECULAR VARIATION. The magnetic variation does not continue the same at any given point, but follows the magnetic pole, which moves slowly from east to west during long periods, and finally returns to its former position. This oscillation is called *secular*[1] *variation.* A map showing lines of declination must, therefore, refer to a particular period, as is the case in the one here given.

DECLINATION OBSERVED IN PARIS.

| YEAR. | Declination. | YEAR. | Declination. |
|---|---|---|---|
| 1580 . . . . . . . | 11° 30′ east. | 1816 . . . . . . . | 22° 25′ west. |
| 1618 . . . . . . . | 8° — " | 1817 . . . . . . . | 22° 19′ " |
| 1663 . . . . . . . | 0° — " | 1823 . . . . . . . | 22° 23′ " |
| 1678 . . . . . . . | 1° 30′ west. | 1827 . . . . . . . | 22° 20′ " |
| 1700 . . . . . . . | 8° 10′ " | 1828 . . . . . . . | 22° 05′ " |
| 1780 . . . . . . . | 19° 55′ " | 1829 . . . . . . . | 22° 12′ " |
| 1805 . . . . . . . | 22° 05′ " | 1835 . . . . . . . | 22° — " |
| 1814 (Maximum) . | 22° 34′ " | 1854 . . . . . . . | 22° 10′ " |

*Observations made at Paris*, during nearly three centuries, show the following results: —

(1) The extent of secular variation in a period of 234 years (2⅓ centuries), was over 34°. (2) During this period of 234 years, from 1580 to 1814, the needle moved towards the west. (3) In 1663 the declination was zero, the needle pointing due north. The maximum westward declination, attained in 1814, was 22° 34′. (4) Since 1814 it has returned slowly towards the east, advancing but 24′ in 40 years. (5) The rate of secular variation is not uniform, but is greatest near the minimum. and least near the maximum, of declination

MINOR VARIATIONS in declination have been observed, coinciding with periods of the day and year, and seeming to be in close connection with the temperature of the atmosphere and the position of the Sun.

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[1] Latin *seculum*, a century.

## IV. Magnetic Inclination.

**Definition.** Magnetic *inclination* is the *dip*, or departure from a horizontal position, of a needle suspended so as to move freely in a vertical plane, and adjusted in the magnetic meridian. In the northern hemisphere, the north pole of the needle dips, in the southern, the south pole.

2. **Degree of Dip.** The magnetic inclination *is greatest* at the magnetic pole, where the needle assumes a vertical position. Passing towards the equator the inclination becomes less and less, until a line is reached in which the needle is horizontal.

The line of no inclination constitutes a *magnetic equator*, and the lines of equal inclination, *magnetic parallels*. They coincide in a remarkable manner with the *isothermals*, or lines of equal mean temperature on the globe, thus indicating a close connection between the distribution of magnetism and of solar heat.

3. **Variations.** Magnetic inclination, like declination, is subject to both periodical and secular variations. The latter is shown by the following table:—

INCLINATION OBSERVED AT PARIS.

| Year. | Inclination. | Year. | Inclination. | Year. | Inclination. |
|---|---|---|---|---|---|
| 1671 . . . . . | 75° — | 1806 . . . . . | 69° 12′ | 1825 . . . . . | 68° — |
| 1780 . . . . . | 71° 48′ | 1814 . . . . . | 68° 36′ | 1831 . . . . . | 67° 40′ |
| 1798 . . . . . | 69° 51′ | 1820 . . . . . | 68° 20′ | 1853 . . . . . | 66° 28′ |

Since the year 1671, it appears, the inclination of the needle at Paris has steadily decreased from three to five minutes per year.

### ANALYSIS OF SECTION VI.

**I. Magnetism.**

1. Phenomena Exhibited.
    a. Where first observed.
    b. Origin of name magnet.
2. Artificial Magnet.
    a. How produced.
    b. Magnetic needle.
    c. Mariner's compass.

**II. Properties of Magnets.**

1. Polarity.
    a. How exhibited.
    b. Poles of magnet.
    c. Subdivision of magnet.
2. The Earth a Magnet.
    a. Property of magnet exhibited by it.
    b. Position of magnetic needle.
    c. Relative position of poles of needle and of Earth.
3. Magnetic Poles of Earth.
    a. Their geographical position.
    b. Magnetic meridians.
    c. Direction of magnetic needle.

**III. Magnetic Declination.**

1. Definition.
    a. Lines of no declination. { Definition. Number. Position.
    b. Direction of declination. { East hemisphere. West hemisphere.
2. Secular Variation.
    a. Definition.
    b. Results of observation in Paris.
        (1) Extent of variation.
        (2) Minimum and maximum.
        (3) Direction of change before 1814.
        (4) Direction of change since 1814.
        (5) Rate of change.
3. Minor Variations.

**IV. Magnetic Inclination.**

1. Definition.
2. Degree of Dip.
    a. How varying.
    b. Magnetic equator and parallels.
3. Variation of Inclination.
    a. Kinds of variation.
    b. Results of observation in Paris.

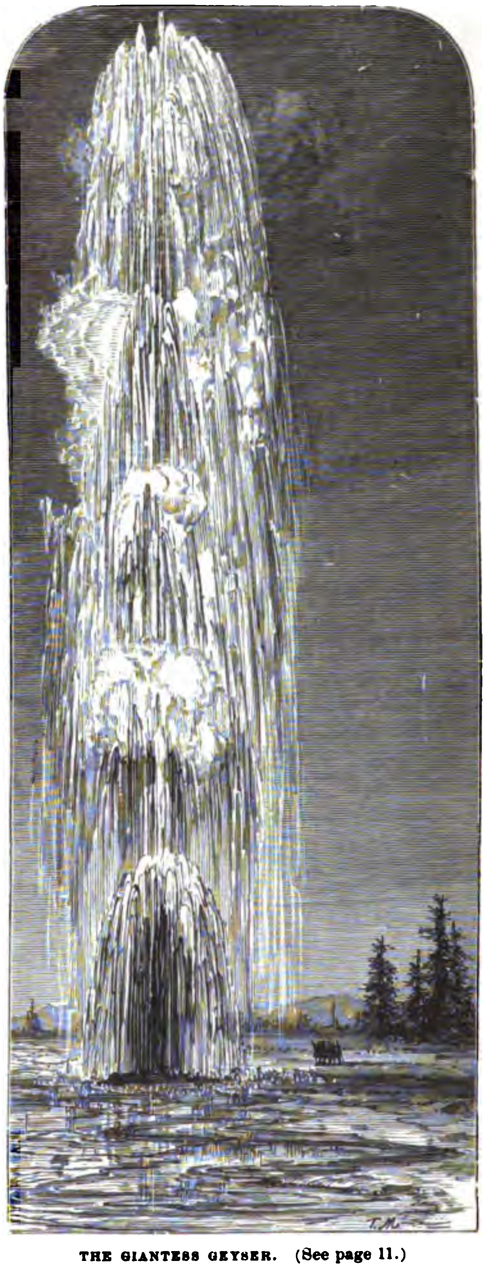
# VII.—TEMPERATURE OF THE TERRESTRIAL GLOBE.

## I. Evidences of Internal Heat.

That the interior of the terrestrial globe maintains a high temperature, independently of the influence of the Sun upon the surface, is proved by a variety of phenomena.

1. Warm Springs are numerous in nearly all parts of the Earth, varying in heat from a degree but slightly above the mean annual temperature of the place where they occur, to the boiling point.

The temperature of ordinary springs and wells does not differ materially from the mean annual temperature of the ground and the air above it, and is comparatively uniform throughout the year. Thus in winter the water is warmer than the air; in summer, colder.



THE GIANTESS GEYSER. (See page 11.)

*Explanation of the cut.* The geysers seem to be due to the unequal heating of a column of water in an open vertical shaft, traversing hot volcanic strata.

Steam escapes when the temperature of the water enables its expansive force to overcome the pressure of the atmosphere, viz., at 212° Fahr., at sea level. But at the bottom of a shaft of 68 feet, for instance, the pressure being equal to three atmospheres, a much higher degree of heat is required. When this is reached, steam is formed, which, in ascending, partially expels the water from the shaft. The pressure being thus relieved, new masses of steam develop rapidly, and the explosions become so frequent, and the successive jets so powerful, as to form a continuous column of boiling water and vapor rising in the air. When the explosions cease, the water, now cooled, falls back into the shaft, and after a time of rest the process recommences.

The correctness of this view is confirmed by the fact that the temperature within the shaft increases towards the bottom. In the *Great Geyser* of Iceland, Bunsen found the temperature at the surface of the water to be from 169° to 192° Fahr.; but at the depth of 72 feet it was 261° before an eruption, and 252° after, or from 40° to 50° higher than boiling water.

Springs, of whatever temperature, are simply the return of water to the surface, after circulating among the Earth's strata[1] at a greater or less depth. When it entered the ground it could not have been warmer than the surrounding atmosphere; hence the higher temperature of warm, or *thermal*, springs must have been imparted to the water by the strata among which it has circulated.

2. Active Volcanoes are found in all latitudes, ejecting, from time to time, streams of red-hot lava; hence it is evident that at

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[1] Beds of earth or rock, formed by natural causes, and usually consisting of a series of layers.

### OLD WORLD.

EUROPE AND ASIA — FROM WEST TO EAST.

| Plateaus. | Eng. feet. | Mountains. | Eng. feet. |
|---|---|---|---|
| Plateau of Spain . . . . . . | 2,300 | Pyrenees, Pic Anéthou . . . | 11,168 |
| " Bavaria . . . . . | 1,800 | Alps, Mt. Blanc . . . . . . | 15,780 |
| " Asia Minor . . . . | 2,500 | Caucasus, Mt. Elbourz . . . . | 18,524 |
| " Armenia . . . . | 5,000 | Hindoo Koosh . . . . . . | 20,000 |
| " West Iran, Persia . | 4,000 | Karakorum Chain, Mt. Dapsang | 28,278 |
| " East Iran, Afghanistan | 6,000 | Dhawalagiri, Himalaya Mts. . | 26,861 |
| " Western Thibet . . | 16,000 | Mt. Everest, " " . | 29,002 |
| " Eastern Thibet . . | 11,000 | Chumalari, Bhootan . . . . | 23,944 |

## VI. Maximum Altitude in Tropical Regions.

*The continental reliefs, as a whole, begin with vast low plains about the arctic circle, and increase in altitude towards the equatorial regions.*

The *culminating regions* of the New World extend from 20° north latitude to 16° south; those of the Old World from 28° north latitude in Asia, to 5° south in Africa.

The *effect* of this law is to temper the burning heat of the tropical regions, and give them a variety of climate not otherwise belonging to them. If this order were reversed, and the elevations increased towards polar latitudes from low plains at the equator, those regions of the globe, at present the most highly civilized, would be a frozen and uninhabited waste.

## VII. Predominant Relief Form of Individual Continents.

*In general, each continent has one dominant form of relief, which gives it a special character, exerting a powerful influence upon its climate, and upon its functions both in nature and in human history.*

The Americas are the *continents of low plains.* The great fertile basins of the Mississippi, the Amazon, and other mighty rivers, are the most valuable and characteristic regions of these continents.

Africa has no extended low plain, but is filled with vast tablelands. It is the *continent of plateaus*, inferior in moisture and vegetation, superior in temperature and in the development of animal life.

Europe, in its western and most important half, is but a network of mountain chains, without high or extensive plateaus. It is the *continent of mountains.*

Asia, the largest continent, is the full type of all the others. It has all the forms of relief on the grandest scale, in nearly equal proportions, and in the greatest variety of combination. In the north and west are the most extensive plains of the earth; in the centre, the highest and largest plateaus; and in the south, the loftiest mountain chains.

## VIII. Summary.

All that has been said of the reliefs of the globe may be summed up in a single grand law, as follows: —

*All the long, gentle slopes descend towards the Atlantic Ocean and its prolongation, the Arctic; while all the short and rapid slopes are directed towards the Pacific, and its dependent, the Indian Ocean, the highest lands being adjacent to the shores of the greatest oceans.*

## IX. Formation of Reliefs.

These general laws which regulate the elevations of our globe seem to indicate a common *geological cause*, which may, perhaps, be found in the gradual cooling of our planet.

The *operation of this cause* may be conceived as follows: —

The heated interior of the Earth continues to cool and to contract through the progress of ages, while the hardened outer crust, receiving from the sun an amount of heat about equal to that which it radiates into space, contracts at a much slower rate, if at all.

Thus, in time, the interior becomes too small for the crust, which, obeying the force of gravity, collapses, the circumference adjusting itself to the decreasing volume within. Vast areas subside with the shrinking interior, while the adjacent portions, too large for the space left for them to occupy, are forced into great folds and ridges by lateral pressure.

Upon the subsiding areas, the waters, before spread over the entire surface of the globe, gather together, and the folded and uplifted areas are left more or less uncovered. Thus were formed the great basins of the Atlantic, Pacific, and Indian Oceans, with the three pairs of continents upraised between them.

*Confirmation of this view* of the cause of grand upheavals is found in the fact, pointed out by Professor Dana, that the height of the border mountains and plateaus of the continents is proportioned to the width of the oceans which bathe their bases.

In the American continents, for example, the high chains of the Sierra Nevada and Andes mountains skirt the shores of the Pacific, the greater ocean; and near the Atlantic are the low Appalachian Mountains and Brazilian plateau. A similar arrangement of elevations appears in the other continents; while the interior of all, more remote from the upheaving force, remains comparatively depressed. Thus is explained the typical structure of the continents, noticed in the preceding sections and in the first law of relief.

The almost infinite variety of inequalities in the Earth's surface, therefore, is subject to a few general laws. Here, as elsewhere, everything has been made with order and in due measure, and doubtless also with reference to a final aim which science seeks to discover by patient and intelligent research.

### ANALYSIS OF SECTION IX.

**I. Typical Structure of Continents.**

1. Law Stated.
2. Examples.

**II. Position of Main Axis.**

1. Law Stated.
2. Examples.

**III. Direction of Elevations.**

1. Law Stated.
2. Directions Specified. Examples.
3. Directions Named.

**IV. Contrasting Plans in Old and New World.**

1. Law Stated.
2. Effect on Structure of New World.
3. Effect on Structure of Asia-Europe.
4. Effect on Structure of Africa.
5. Asiatic Islands, how formed. Antilles.

**V. Position of Maximum Elevation in Continents.**

1. Law Stated.
2. Example in New World.
3. Example in Asia-Europe.
4. Example in Africa.
5. Example in Australia.
5. Tables of Altitudes.

**IV. Position on Globe of Maximum Elevations.**

1. Law Stated.
2. Culminating Region of New World. Of Old World.
3. Effect of this Law on Climates.

**VII. Dominant Relief Form of Individual Continents.**

1. Law Stated.
2. Examples.
    a. American Continents.
    b. Africa.
    c. Europe.
    d. Asia.

**VIII. Summary of Laws of Relief.**

**IX. Formation of Reliefs.**

1. Common Cause Underlying Reliefs.
2. How this Cause operates.
3. Confirmation of this View.
4. Result of Operation of General Causes.

below the surface; but it descends, with increasing latitude, as the difference between the summer and winter temperature of the air increases. In middle latitudes it is found about sixty or eighty feet below the surface.

(2) *Where Made.* Among the wells in which valuable observations have been made are the following: one at *Columbus*, Ohio, 2,775 feet deep; at *Louisville*, Kentucky, 2,086 feet; at *St. Louis*, Missouri, 2,199 feet; at *Grenelle*, near Paris, 2,021 feet deep; at *Neu-Salzwerk*, in Germany, 2,288 feet; and at *Mouillelonge*, in Central France, 2,677 feet.

(3.) *Result of Observations.* The following table, giving the result of observations in the above-named wells, shows that the temperature invariably increases with increasing depth, but the rate of increase is different in different wells.

| WELL. | Depth of Observation. | Temp. Fahr. | Rate of Increase. |
|---|---|---|---|
| Columbus . . . . . . . . | 2,775 | 88.0° | 1° for 73 feet. |
| Louisville . . . . . . . . | 2,086 | 82.5° | 1° " 72 " |
| St. Louis . . . . . . . . . | 2,199 | 80.4° | 1° " 83 " |
| Mouillelonge . . . . . . . | 2,677 | 101.0° | 1° " 51 " |
| Neu-Salzwerk . . . . . . . | 2,288 | 92.5° | 1° " 55 " |
| Grenelle . . . . . . . . . | 1,798 | 82.4° | 1° " 58 " |

3. OBSERVATIONS IN MINES exhibit similar results. The increase of heat downward is constant, but the rate of increase often differs widely even in mines not very far apart, owing probably to difference in the nature of the rocks.

In the Prussian mines, where observations have been made with the greatest care, the most rapid rate observed is 1° Fahr. for 27 feet of descent; and the slowest, 1° for 197 feet, the average being 1° for 92 feet. In the mines of Saxony the average increase is 1° for 72 feet; in six of the largest mines in England, 1° for 44 feet; and in the coal mines of Virginia, 1° for 60 feet. Even the frozen soil of Siberia, having a temperature near the surface of but 10°, shows a steady increase downward at a rate which would free the soil from frost at the depth of 600 feet.

4. THE AVERAGE of all known observations, whether in artesian wells or mines, shows an increase of heat towards the interior of the Earth, at the very rapid rate of about 1° Fahr. for every 55 feet.

5. CONCLUSION. If this average rate continues without interruption, the temperature of boiling water must be reached at the *depth of* 9,000 *feet*, or less than two miles from the surface; and at the depth of *thirty miles* the heat would be sufficient to melt the most refractory substances.

There is, however, some reason to believe that the rate of increase becomes slower at greater depths; and that the *solid crust* of the Earth, enclosing the melted mass, has a thickness varying from 50 to 100 miles.

The *active volcanoes*, pouring out torrents of fiery lava, demonstrate that the conclusion drawn from observations of the Earth's internal temperature is not a fanciful one; for the volcanic phenomena are too general and too closely connected with the great fractures of the Earth's crust to be accounted for, as has been attempted, by merely local chemical causes.

### ANALYSIS OF SECTION VII.

**I. Evidences of Internal Heat of Globe.**
- 1. WARM OR THERMAL SPRINGS.
    - a. Distribution and temperature.
    - b. Source of waters.
    - c. Source of warmth.
- 2. ACTIVE VOLCANOES — CONCLUSION FROM.
- 3. ARTESIAN WELLS AND MINES.
    - a. Depth of observations.
    - b. Result of observations.

**II. Thermal Springs.**
- 1. SITUATION AND TEMPERATURE.
    - a. Where most numerous.
    - b. European springs. { Number. Temperature.
- 2. GEYSERS, HOW EXPLAINED.
    - a. Temperature.
    - b. Where found.
    - c. Great geyser described.
    - d. Other remarkable geysers. Geysers of California.
- 3. WATERS OF THERMAL SPRINGS.
    - a. Character.
    - b. To what due.
    - c. Classification.

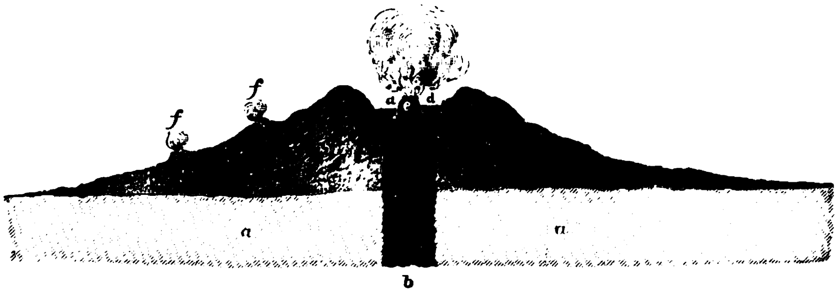
**III. Artesian Wells and Mines.**
- 1. FORMATION OF WELLS DESCRIBED.
    - a. Supposed conditions.
    - b. Effect of drilling.
    - c. Origin of name.
- 2. OBSERVATIONS IN WELLS.
    - a. How made.
    - b. Temperature of ground.
    - c. Mean annual temperature found where.
    - d. Observations. Where made.
    - e. Results.
- 3. OBSERVATIONS IN MINES. EXAMPLES.
- 4. AVERAGE RESULT OF ALL OBSERVATIONS.
- 5. CONCLUSION FROM ALL OBSERVATIONS.
    - a. Temperature at 9,000 feet.
    - b. Temperature at thirty miles.
    - c. Probable thickness of Earth's crust.
    - d. Conclusion, how sustained.

## VIII.—RESULTS OF INTERNAL HEAT—VOLCANIC PHENOMENA.

### I. Nature and Formation of Volcanoes.

1. A VOLCANIC MOUNTAIN is usually of conical form, with a circular basin or depression, called a *crater*, at its summit. In the centre of the crater is the mouth of a perpendicular shaft or chimney, which emits clouds of hot vapor and gases; and in periods of greater activity, ejects ashes, fragments of heated rock, and streams of fiery lava.

2. The VOLANIC CONE IS FORMED by the accumulation of the ejected materials, in a series of concentric layers, around the mouth of the shaft. These layers are distinctly visible on the inner walls of the crater, and in every part of the mass which is open to observation through crevices.



*a a* Strata not volcanic. *b* Chimney. *c c* Lava and ashes. *d d* Crater. *e* Cone of eruption. *f f* Later eruptions, parasitic cones.

FORMATION AND STRUCTURE OF VOLCANIC CONES.

This *mode of formation* not only explains the conical form of volcanoes, but distinguishes them from the mountains and mountain chains which are the result of the folding or uplifting of the solid crust of the Earth, and which form the skeletons of the continents and islands.

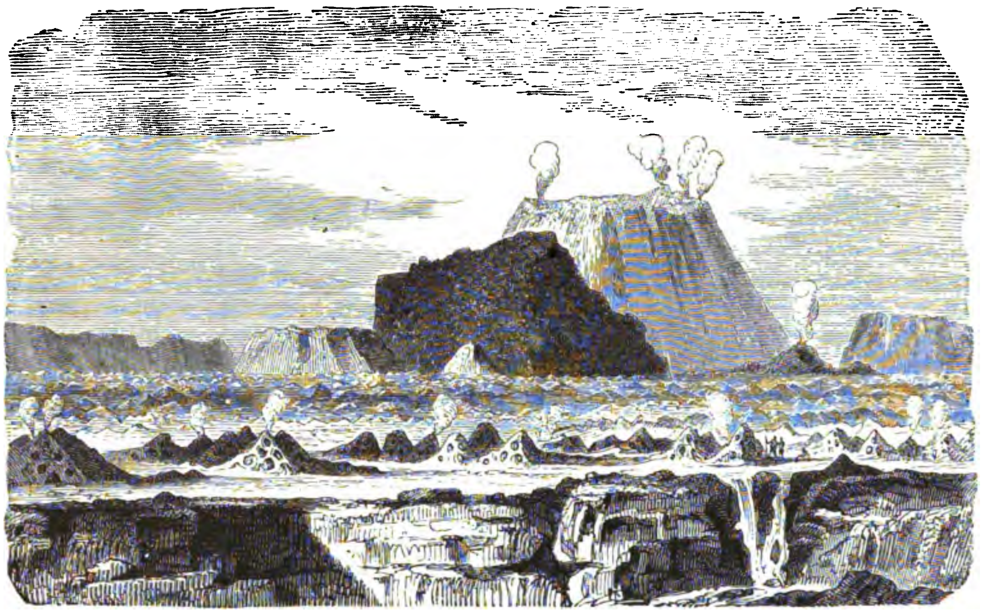
3. THE FORM OF VOLCANIC CONES appears to depend upon the relative fluidity of the ejected materials by which they were built up. In general the more liquid the lava, and the smaller the quantity of solid materials, the broader and flatter are the cones. The volcanoes of the Sandwich Islands, noted for the liquidity of their lavas and an almost entire absence of

ashes, are remarkable for their flattened form and the slight inclination of their slopes.

Dana estimates the average slope of Mauna Loa to be only from six to eight degrees. A horizontal section 1,800 feet below the summit, would be nearly twenty miles broad; and the top, in which the crater is sunk, though nearly 14,000 feet in elevation, is a plain so level that the surrounding ocean cannot be perceived from it.

In volcanoes where the lavas are less liquid and ashes abound, as in Vesuvius and Etna, the form is more conical and the slopes are more steep, being from twenty to thirty-five degrees. Volcanoes which eject only ashes and fragments of rock, as those of the Andes, are still more steep and pointed in form; as shown in the cones of Cotopaxi and Arequipa. In the volcanoes of Iceland, where the lava is viscous and alternates with ashes, the form resembles a dome.

4. Volcanic Products. *Volcanic ashes*, when examined under a microscope, are found to be simply pulverized lava, frequently in minute crystals, and bear no resemblance to ashes in the ordinary sense of the term.



VIEW OF JORULLO.

They occasionally form a fine powder, which is carried by the wind to a distance of hundreds of miles. Coarser materials take the name of *volcanic sand.*

Irregular fragments of *solidified lava*, of all sizes, including large pieces of the walls of the crater, are at times ejected with great violence. Humboldt speaks of a mass of several tons weight which was thrown to the distance of seven miles from the crater, in an eruption of Cotopaxi.

The *lava stream*, when flowing white hot from the crater, is not unlike a jet of melted iron escaping from a furnace, and moves at first with considerable rapidity. It soon cools on the surface, and becomes covered with a hard, black, porous crust, while the interior remains melted and continues to flow. If the stream is thick, the lava may be found still warm after ten or even twenty years.

5. The amount of matter ejected by volcanoes is very great. The whole island of Hawaii, the largest of the Sandwich Islands, seems to be only an accumulation of lava thrown out by its four craters. All high oceanic islands are of the same character. Iceland, with an area of 40,000 square miles, is a vast table-land from 3,000 to 5,000 feet in elevation, composed of volcanic rock similar to the lavas still ejected by its numerous volcanoes.

The *formation of a new volcano* which occurred in Mexico in 1759, and has been described by Humboldt, exhibits the magnitude of volcanic eruptions. In a fertile and highly cultivated plain, with an elevation of 2,000 feet, the ground was rent; and at points along the fissure were ejected an immense amount of lava and fragments of rock, which accumulated in six distinct volcanoes. The central one, *Jorullo*, rises 1,600 feet above the plain; and all rest on a bed of volcanic rock studded with small steaming cones, and gently rising towards the centre where it is 500 feet thick. This region, covering an area of four square miles, now bears the name of the *Malpays*, or "bad lands."

6. The number of volcanoes, active and extinct, is variously estimated. Dr. Fuchs enumerates 672, of which 270 are active. Of the active volcanoes 175 are on islands, and 95 on the continents near the sea-shores.

7. The height of volcanoes varies from submarine cones to an elevation 23,000 feet above the level of the sea. If such volcanoes as Mauna Loa, 14,000 feet high, have their base at the bottom of the deep waters which surround them, the total elevation of such a structure may reach that of the highest mountains on the globe.

## II. Volcanic Activity.—Vesuvius.

Nearly all active volcanoes have intervals of comparative repose, interrupted by periods of increased activity, which terminate in a violent ejection of matter from the interior, during which the volcano is said to be in a state of *eruption.*

The phenomena which characterize these differing phases of volcanic activity may be best made clear by describing them as actually observed in Vesuvius, one of the most carefully studied and most active volcanoes of modern times.

This remarkable mountain may be considered as typical, for the phenomena exhibited by it are more or less common to all active volcanoes.

*Each volcano may differ* from this in the relative amount of ashes and broken fragments compared to the liquid lava; in the violence and frequency of the eruptions; the form and size of the crater; the greater or less steepness of the cone; the composition of the lavas, and other secondary circumstances: but the general course and character of the phenomena show a remarkable similarity.

Even submarine volcanoes do not seem to differ materially from others, though the arrangement of the ejected materials, in the formation of a submarine cone, is no doubt modified to a certain extent.

## III. Vesuvius, the Typical Volcano.

1. Situation and Form. Vesuvius is a solitary mountain rising to the height of nearly 4,000 feet, from the midst of a highly cultivated plain which borders upon the shores of the Bay of Naples. Though the mountain has a regular conical form, two summits, very nearly equal in height, are visible from Naples—Monte Somma on the north, and Vesuvius proper on the south.

*Monte Somma* is only the northern half of the crater-rim of the old Vesuvius, the southern half of which was destroyed in the year 79 A.D., in which occurred the first eruption of that volcano in historical times. *Vesuvius proper* is the new cone which has gradually grown out of the old crater, by the ejection of materials in subsequent eruptions. After an eruption the energies of the volcano seem to be exhausted, and it enters into a state of relative repose.

2. State of Repose. At the close of the great eruption of 1822, the crater was emptied to the depth of 700 or 800 feet; its rim was broken on the south, and sunk several hundred feet; and the lava, deeply sunk in the chimney, had

almost disappeared from sight. Only a few jets of vapor and gases, called *fumaroles*, escaped from fissures in the walls and at the bottom of the crater.

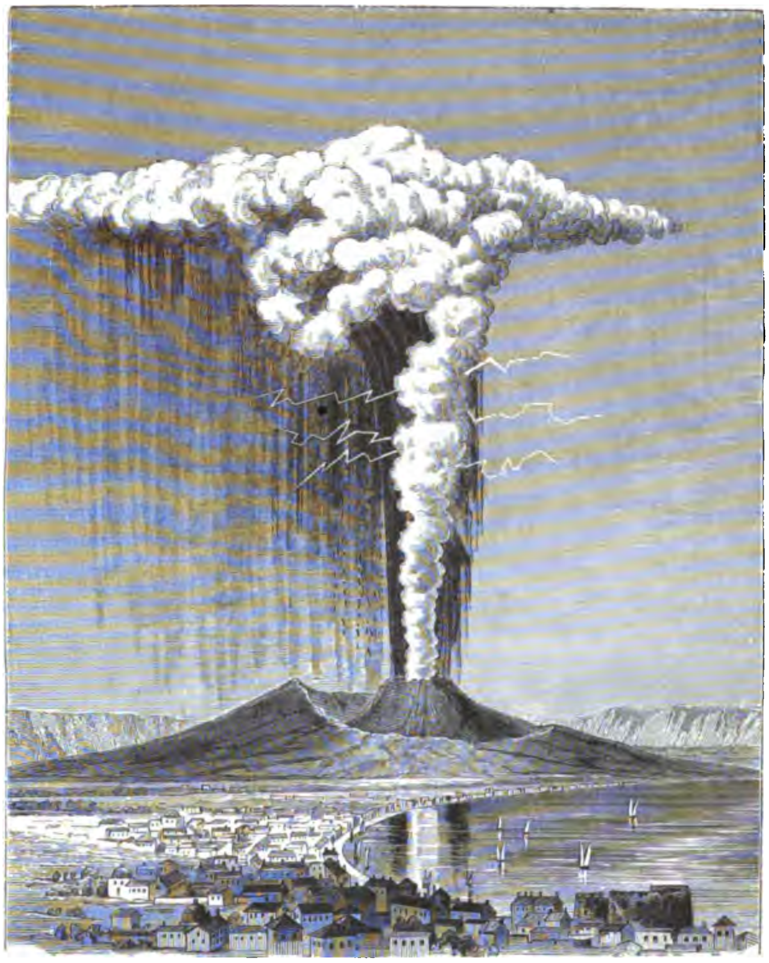
Gradually the fumaroles become more numerous, and their united vapors form a column constantly ascending from the crater. The lava re-appears in the chimney, and on its surface there is formed a crust which, bursting under the pressure of imprisoned steam, sends fragments of red-hot lava into the air. These falling back accumulate around the mouth of the chimney, and build up a *cone of eruption* within the crater of the main volcanic cone, as Vesuvius proper within the crater of the old Monte Somma. A smaller cone of this description could be seen within the crater of Vesuvius in 1828.

This cone grows constantly in dimensions, occasional overflows of lava and the materials which fall from the crumbling walls of the crater contributing to its increase, until the crater is full to the brim, or the cone of eruption rises even higher, as was the case in 1756. When the crater is thus full, and its mouth choked up, the expansive forces below rapidly accumulate, and soon there are indications of an approaching eruption.

3. Premonitions of an Eruption. In Vesuvius among the indications of the approach of a great eruption is the drying up of the wells and springs, probably due to the increasing heat of the ground, causing internal evaporation, and to the formation of numerous fissures in which the underground waters disappear. Loud subterranean noises like the reports of distant artillery, shocks of earthquake which shake the neighborhood of the volcano, and a large increase of the volume of vapors which escape from the boiling lava imprisoned in the chimney, indicate the struggle going on within the mountain.

4. The eruption begins generally with a tremendous explosion which seems to shake the mountain to its very foundations, and hurls into the air dense clouds of vapor and ashes. Other explosions succeed rapidly, and with increasing violence, each sending up a white, globular cloud of steam, or aqueous vapor. This long array of clouds, accompanied by dark ashes, volcanic sand, and fragments of red-hot lava of all sizes, soon forms a stupendous column.

When checked in its ascending motion by the action of gravity, the column expands at the top, its form resembling an immense umbrella, or the Italian pine, to which it has often been compared. In the eruption of 1822, remarkable for its violence and the abundance of ashes, the height of the umbrella was estimated at 7,000 feet, and in that of 1779, at 10,000 feet.



VESUVIUS IN ERUPTION.

Finally the boiling lava overflows the rim of the crater, and descends in fiery torrents down the slopes; or, bursting the mountain by its weight, finds a vent through some fissure far below the summit. After the expulsion of the lava the eruption is generally near its end, though it does not necessarily terminate at once. Alternate phases of outbursting steam, ashes, and lava may continue with more or less violence for weeks or even months.

5. Atmospheric Phenomena. The sudden condensation of the enormous accumulation of hot vapor thrown into the air by the eruption, gives rise to striking atmospheric phenomena. Vivid flashes of lightning start from all parts of the column, and play about the clouds above; and often a local thunderstorm, formed in the midst of a clear sky, pours a heavy rain of warm water and ashes upon the slopes of the mountain. The hot, destructive mud torrents, created by these rains, have often been mistaken for lava streams.

The majesty of the spectacle is still greater at night. Though flames of burning gases are of rare occurrence, the clouds and column of vapor are strongly illuminated by the reflection of the white-hot lava within the crater; and fragments of this lava constantly thrown into the air give the column all the brilliancy of a gigantic piece of fire-work. The sky itself, far and wide, partakes of the same vivid coloring, and the whole scene resembles a vast conflagration.

6. Periods of Eruption. A series of eruptions, separated by intervals of but few years, during which indications of activity are still numerous, constitutes a *period of eruption*. The history of Vesuvius shows a number of such periods separated by centuries of almost absolute repose, in which the volcano seemed to be extinct.

At the birth of Christ, Vesuvius was described by the Roman geographer, Strabo, as a burnt mountain, but it had never been known to show any activity. Its crater, nearly full, was covered with a dense forest, and its slopes adorned with cultivated fields, villages, and cities.

In the year 63 several shocks of earthquake startled the inhabitants of its delightful slopes, and sixteen years later, in 79 A.D., the first eruption occurred, after which the northern half of the mountain alone remained. The southern half was ground to powder, and the rain of hot, wet ashes was so abundant as to cover the whole neighborhood with a deep layer of volcanic materials, burying the flourishing cities of Herculaneum and Pompeii, which have been recently exhumed from beneath several yards' depth of volcanic tufa. No lava, however, is mentioned in the descriptions of this eruption.

From that time to the year 1036 only seven eruptions are recorded, and lava streams are noticed for the first time. After two others, occurring in 1049 and 1138, the mountain entered into a period of repose which, interrupted only by slight eruptions in 1306 and 1500, lasted nearly 500 years.

In 1631, when the volcano had been so long dormant that its slopes were cultivated to the foot of the cone of eruption, and the walls of the crater covered with forests, an eruption took place surpassing in destructiveness all others on record.

The umbrella-shaped mass of vapors and ashes extended above the clouds, and, spreading in every direction, covered a large extent of country with a thick layer of volcanic materials, destroying all vegetation. The rain of ashes extended eastward even beyond the Adriatic Sea. Torrents of hot mud, and seven streams of fiery lava, flowing with unusual rapidity down the mountain slopes to the sea, completed the work of destruction. The eruption continued nearly three months, and a number of beautiful cities and villages were almost or entirely destroyed.

This great eruption was followed by a rest of thirty years; but from 1660 to the present time, eruptions have occurred at intervals not exceeding ten years. That of 1794 was the most imposing and destructive which has occurred since 1631. The recent eruption of 1872 is described as remarkable both for the immense quantity of lava ejected, and the exceeding brilliancy of the spectacle presented.

7. Some important contrasts to Vesuvius are presented by other noted volcanoes, occasioned probably by differences in height, and in the size of the crater.

In *Stromboli*, a volcano less than 3,000 feet in elevation, situated on one of the Lipari Islands, the eruptions are continuous, and all from the crater. In *Vesuvius*, 4,000 feet high, the eruptions occur at irregular intervals, and the number from the crater is about equal to that from fissures in the sides.

In *Etna*, a volcano nearly 11,000 feet high, situated on the island of Sicily, the eruptions are less frequent than those of Vesuvius, and are mainly from the sides. It seems that the pressure of the column of lava in the lofty chimney, combined with the expansive force of the imprisoned vapors, is sufficient to burst its walls and cause deep fissures through which both liquid lava and ashes escape. The great cone is studded with more than 200 smaller or *parasitic cones*, formed by the lateral eruptions and arranged mainly on straight lines radiating from the great crater.

The *inference* is, therefore, that the lower the volcano, the more easy and frequent are its eruptions, and the greater the proportion from the top; the higher the volcano and the enclosed column of lava, the greater is the pressure on the walls of the chimney, the more frequent the bursting of the mountain and the lateral eruptions, and the more numerous are the parasitic cones.

The volcanoes of the Andes form an *apparent exception* to this law. Many of them have an altitude of more than 20,000 feet, yet the eruptions are wholly from the top. This is accounted for by the fact that the volcanic peaks rest upon a vast and elevated mountain system which is too massive to be rent by the internal pressure. The enclosed column of lava, unable to reach the elevated crater, is tossed about in the chimney and escapes in the form of ashes and coarser fragments, but scarcely ever in a fluid condition.

The volcanoes of the Sandwich Islands, remarkable for their exceedingly flattened form and the vast size of their craters, are distinguished by the absence of ashes and the usually quiet flow of their lavas from the crater. Extensive lateral eruptions are, however, frequent in Mauna Loa.

### ANALYSIS OF SECTION VIII.

**I. Nature and Formation of Volcanoes.**

1. Volcano Described.

2. Volcanic Cone.
   a. Mode of formation.
   b. Evidences of this formation.
   c. Effect of formation.

3. Form of Volcanic Cones.
   a. Governed by what.
   b. Examples. { Volcanoes of Sandwich Islands.
      Vesuvius and Etna.
      Volcanoes of Andes.
      Volcanoes of Iceland.

4. Volcanic Products.
   a. Ashes.
   b. Sand.
   c. Lava fragments.
   d. Lava stream. { Appearance.
      Process of cooling.

5. Ejected Matter.
   a. Relative amount of.
   b. Examples. { Hawaii.
      Iceland.
      Jorullo.

6. Number of Volcanoes.
   Active. Extinct. Position.

7. Height of Volcanoes.

**II. Volcanic Activity.**

   a. Activity, how varying.
   b. Typical volcano.
   c. How volcanoes differ.
   d. In what respects similar.

**III. Vesuvius.**

1. Position and Form. Why two Summits.

2. State of Repose.
   a. Early condition after 1882.
   b. Later condition.
   c. Cone of eruption. { How formed.
      Size attained.

3. Premonitions of Eruption.
   a. By wells and springs.
   b. Noises.
   c. Earthquakes.

4. Eruption.
   a. Ejection of vapors and solid matter.
      Description. Amount.
   b. Ejection of liquid lava.
   c. Subsequent conditions.

5. Atmospheric Phenomena accompanying Eruptions.
   a. Observed by day.
   b. Observed by night.

6. Periods of Eruption.
   a. What constitutes a period.
   b. Examples in history.
   c. Results of eruption in 79 A.D.
   d. Results of eruption of 1631.
   e. Condition since 1631.

7. Contrasts to Vesuvius.
   a. Contrasts due to what.
   b. Eruptions of Stromboli.
   c. Eruptions of Vesuvius.
   d. Eruptions of Etna.
   e. Inference drawn.
   f. Apparent exception. { Where occurring.
      How explained.

## IX.—RESULTS OF INTERNAL HEAT (*continued*).

### I. Relative Positions of Volcanoes.

1. Lines of Volcanoes. Volcanoes, though they are but local and apparently independent accumulations of materials, ordinarily occur in lines more or less irregular.

The six *volcanoes of Mexico*, among which Orizaba and Popocatepetl are the greatest, are on a line which, when prolonged into the Pacific, strikes the volcanic island of Socorro. The *volcanoes of South America* are all on the line of the Andes; and those *of North America* on the line of the Sierra Nevada and Cascade Mountains. Numerous examples are also found in other quarters of the globe.

An *apparent exception* to this rule is seen where volcanoes seem isolated, or form groups consisting of a central volcano surrounded by secondary cones. But even in this case the linear arrangement is apparent, since the groups themselves form long bands, as in the Polynesian islands; and in the larger groups the disposition of the individual volcanoes in parallel lines is obvious, as in Iceland and the Sandwich Islands.

2. General Distribution of Volcanoes. Nearly all the volcanoes on the Earth's surface are situated along the mountain ranges and belts of islands which skirt the shores of the continents, while the interior is almost destitute of them. Omitting a few extinct craters, the only well authenticated exception to this rule is found in the few volcanoes around the Thian-Shan Mountains, in the heart of the great Asiatic continent, nearly 2,000 miles from the sea.

### II. Volcanic Zones.

1. Two great terrestrial zones include nearly all the known volcanoes of the globe, arranged in long bands or series, or in isolated groups.

The *first zone* includes the vast array of mountain chains, peninsulas, and bands of islands which encircle the Pacific Ocean with a belt of burning mountains. Within it occur, in the New World, (1) the Andes Mountains, with three of the most remarkable series of volcanoes—those of Chili, Bolivia, and Ecuador—separated by hundreds of miles; (2) the volcanic group of Central America; (3) the series of Mexico; (4) the series of the Sierra Nevada and Cascade Mountains; (5) the group of Alaska; and (6) the long series of the Aleutian Islands.

In the Old World are (1) the series of Kamchatka and the Kurile Islands; (2) the group of Japan; (3) the series south of Japan, including Formosa, the Philippine and the Molucca Islands; and (4) the Australian series, including New Guinea, New Britain, New Hebrides, and New Zealand. In this vast zone there are not less than 400 volcanoes, 170 of which are still active.

The *second zone*, though less continuous, is hardly less remarkable. It is the belt of broken lands and inland seas, which, extending round the globe, separates the northern from the southern continents, and intersects the first zone, in the equatorial regions, nearly at right angles.

This zone includes (1) the volcanic regions of Central America and Mexico, and the series of the Lesser Antilles; (2) the groups of the Azores and Canary Islands; (3) the Mediterranean islands and peninsulas, including all the active volcanoes of Europe; (4) Asia Minor with numerous extinct volcanoes; (5) the shores of the Red Sea and Persian Gulf, and the two Indias, rich in traces of volcanic action; (6) the East Indian Archipelago with hundreds of burning mountains; and (7) the Friendly Islands and other volcanic groups of the central Pacific.

In this zone there are no less than 160 volcanoes, so that the two volcanic zones together contain 560, or five-sixths of all known.

The volcanic forces display the *greatest intensity* at the intersections of the two volcanic zones, in Central America and the East Indian Archipelago, nearly one-third of all known volcanoes occurring in these two regions. Central America, Mexico and the Antilles include 85 volcanoes, while the East Indian Archipelago possesses 117.

The *volcanoes not included* in these two great zones are isolated, in the midst of the oceans, or in the broken polar lands. The most noted are the Sandwich Island group, in the Pacific; Bourbon and Mauritius, in the Indian Ocean; Cape Verd Islands, Ascension, St. Helena, and Tristan da Cuñha, in the Atlantic; Iceland and Jan Mayen, in the Arctic Ocean; and Erebus and Terror, in the Antarctic.

## III. Causes of Volcanic Action.

1. THE PECULIAR DISTRIBUTION of volcanoes suggests the nature and causes of volcanic action, which must not be confounded with that more general force which has uplifted the continents and depressed the basins of the oceans.

Three facts are obvious and significant, namely: (1) Nearly all volcanoes are either along the highest border of the continents, or in the great central zone of fracture. (2) Most of the volcanic groups exhibit a linear arrangement. (3) The agent at work in these mighty engines is mainly vapor of water, or steam power.

2. THE PRIMARY SOURCE of volcanic action is the heated condition of the Earth's interior, of which we have evidence so conclusive. The effect of this condition will necessarily *be most intense* along the deep fissures which establish a ready communication between the interior and the surface of the globe.

Nowhere are the *Earth's strata more deeply broken* than on the very edge of the continents; and it is along the mighty chasms caused by the upheaval of these vast land masses, that *mountain chains*, such as encircle the sunken basin of the Pacific, have been raised. There, also, *volcanic vents* abound in long lines, following either the top or the foot of the mountain chains. Similar conditions exist in the zone of fracture.

The *folding and breaking* up of the solid crust of the Earth, and the formation of those great surface features which adorn it, must not be ascribed to the heat of the interior mass, but to its slow cooling and the consequent contraction of its bulk.

*Volcanic action*, therefore, is not the cause but a consequence of the upheaval of mountain chains and continents; and the proximity of volcanoes to the sea does not imply the necessity of sea water to their formation, but is due to the deep fissures in the Earth's crust, along the line of contact of the depressed ocean basin and the uplifted continent.

The rain water which, having entered the ground, instead of re-appearing in the form of springs or artesian wells, penetrates deep into these subterranean cavities, may become so heated, under the high pressure to which it is subjected, as to produce the usual volcanic phenomena.

### ANALYSIS OF SECTION IX.

**I. Relative Position of Volcanoes.**

1. LINES OF VOLCANOES.
    - a. Ordinary arrangement.
    - b. Examples.
    - c. Apparent exception.
2. GENERAL DISTRIBUTION.
    - a. Ordinary situation.
    - b. Exceptions.

**II. Volcanic Zones.**

- a. Number of zones.
- b. Pacific zone. Volcanic regions included.
- c. Transverse zone. Volcanic regions included.
- d. Greatest intensity of volcanic forces.
- e. Volcanoes not included in zones.

**III. Volcanic Action.**

1. NATURE AND CAUSES—HOW SUGGESTED.
    Prominent facts of distribution.
2. PRIMARY SOURCE OF VOLCANIC ACTION.
    - a. Effects, where most intense.
    - b. Strata, where most deeply broken.
    - c. Folding of Earth's crust ascribed to what.
    - d. Volcanic action, how related to upheaval of mountain chain.

# X.—RESULTS OF INTERNAL HEAT (*continued*).

### EARTHQUAKES.

## I. Earthquake Defined.

1. EARTHQUAKES are movements of the Earth's crust, varying in intensity from a hardly perceptible vibration to violent convulsions, which change the face of the ground and overthrow the most substantial works of man.

2. EXAMPLE. The *earthquake at Lisbon*, Portugal, on the morning of November 1, 1755, one of the most appalling in its results, exhibits the nature of these commotions of the Earth's crust, and the phenomena attending them. The day was the festival of All-Saints, and the churches of the city were full to overflowing, when, at forty minutes past nine, a rumbling noise was heard like distant thunder, gradually increasing until it resembled the sound of heavy artillery. A faint shock was followed by a heavier one, and within six minutes 30,000 persons were buried under the ruins of the churches and other edifices; and 30,000 more perished before the end of the catastrophe.

The ground seemed to undulate like the waves of the sea, the surrounding mountains were seen rocking violently on their base, and broad chasms opened in the earth and closed again. More than 3,000 persons had taken refuge from the falling edifices on a broad marble quay just built on the banks of the Tagus, when the sea, which had before receded, came back in a furious wave forty feet high and swallowed up the entire multitude; then rushing upon the city it continued the work of devastation. Similar oscillations of the sea were repeated several times; and when the commotion ceased, several hundred feet of water covered the spot which the quay had occupied.

Fires, kindled in the fallen dwellings, spread over the scene of desolation, creating a vast conflagration which completed the work of destruction. The ground continued to be agitated for several weeks afterwards, and another severe shock occurred in December following.

One of the most remarkable features of this earthquake was the extent of country over which it was felt. All western Europe was agitated; the northern coast of Africa suffered considerably; nearly all the cities of Marocco were destroyed, and fissures, whence streams of water issued, were opened in many places. On some of the West India Islands the sea rose twenty feet, and a similar rise was observed in the harbors of New York and Boston. The entire surface disturbed by this earthquake amounts, according to Humboldt, to four times the area of Europe.

## II. Kinds of Earthquake Movement.

Three kinds of motion are observed in earthquakes.

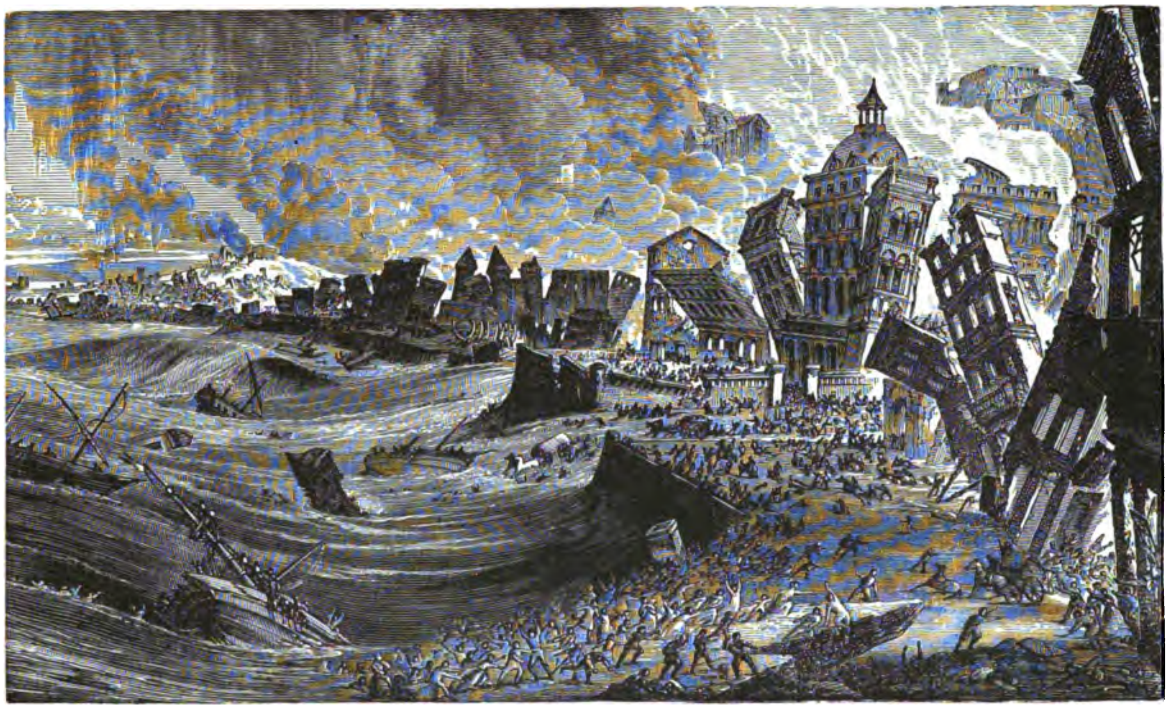
1. The WAVE-LIKE OR UNDULATORY MOTION is most common and least destructive. It appears to be the normal one, and it is possible that the others may be simply the result of various systems of waves intersecting one another. The waves either advance in

one direction, like waves of the sea, or spread from a central point, like ripples produced by dropping a pebble into still water.

The earthquakes of the Andes are chiefly *linear*, being propagated along the mountains, with the undulations perpendicular to the direction of the ranges. The earthquake at Lisbon, described above, was a *central* one, the concentric waves gradually diminishing in intensity with increasing distance from the place of origin.

2. The VERTICAL motion acts from beneath like the explosion of a mine, and when violent nothing can resist its force. The earthquake at Calcutta, in September, 1828, owed its great destructiveness to the fact that the main shock was vertical; and one in Murcia, Spain, in 1829, destroyed or injured more than 3,500 houses.

3. The ROTARY or WHIRLING motion is the most dangerous, but happily the rarest of all. In the great earthquake of Jamaica, in 1692, the surface of the ground was so disturbed that fields changed places, or were found twisted into each other.



EARTHQUAKE AT LISBON.

4. The VELOCITY with which the earthquake wave moves is variable. Humboldt estimates the average rate at from twenty-three to thirty-two miles per minute.

### III. Duration of Earthquakes.

Great earthquakes usually consist of a series of successive shocks, some of which are of extraordinary violence. They may be repeated at longer or shorter intervals, during a period of several days and weeks, or even of several months and years, before the earthquake is at an end.

During the earthquake on the coast of Venezuela, which began on the 21st of October, 1766, and destroyed the city of Cumana in a few minutes, the earth continued to be shaken almost every hour for a period of fourteen months. After the destruction of the beautiful city of Messina, on the island of Sicily, in 1783, the ground continued to be agitated almost daily for ten years.

### IV. Distribution of Earthquakes.

1. GENERAL FACTS. — (1) No part of the globe is absolutely free from earthquakes.

(2) There are circumscribed regions in which the surface is liable to be shaken simultaneously, such a region being called an earthquake area.

(3) The most extensive earthquake areas, and those in which the convulsions are most numerous and violent, are situated within the two great volcanic zones — that is, the coast regions of the Pacific Ocean, and the transverse zone separating the northern from the southern continents.

2. The ANALOGY IN THE DISTRIBUTION of earthquakes and volcanoes is evident, yet the former occupy a far more extensive domain than the latter. Both are most intense in their action along the great fractures of the Earth's crust; yet we are not, on that account, to conclude that the one is the cause of the other; they only require similar conditions for their manifestation.

The immediate *connection of earthquakes with volcanic eruptions* is evident in many instances, yet these are of a special kind. Volcanic eruptions often take place without earthquakes, as in the Sandwich Islands; and many severe earthquakes occur in regions far removed from any active volcano, and destitute of volcanic rocks. Even in volcanic districts the most extensive earthquakes bear apparently no relation to the surrounding volcanoes. The two sets of phenomena may have a common cause, but they must not be confounded or considered as necessarily belonging to the same class.

### V. Relation to Atmospheric and Astronomical Conditions.

*Within the tropics*, especially, earthquakes are most frequent in that part of the year in which the greatest atmospheric disturbances take place. They are most dreaded at the beginning of the rainy season, when the monsoons[1] are changing their direction. In the Molucca Islands the inhabitants, at this period, forsake their houses for greater safety, and shelter themselves under tents or the lightest bamboo structures until the danger is past.

Perrey, by comparing 7,000 observations, found the number of earthquakes occurring at the syzygies — when the attraction of the Sun and Moon is combined and the Moon is nearest the Earth — greater than at the time of the quadratures, when the Moon is most distant; also that, during an earthquake, the shocks are more frequent where the Moon is on the meridian. Wolf finds a coincidence with the periodicity of the Sun's spots, the years in which these are most numerous being those in which earthquakes are most frequent.

### VI. Theory of Earthquakes.

A GENERAL CAUSE NECESSARY. No satisfactory explanation of the phenomenon of earthquakes has as yet been proposed. Local earthquakes, preceding or accompanying a volcanic eruption, are doubtless due to the action of the volcano; but all which take place outside of volcanic districts, and especially those general convulsions, disturbing areas hundreds of thousands of miles in extent, must be assigned to some more general cause. This cause may possibly be found in the constantly increasing tension produced in the Earth's strata, by the steady

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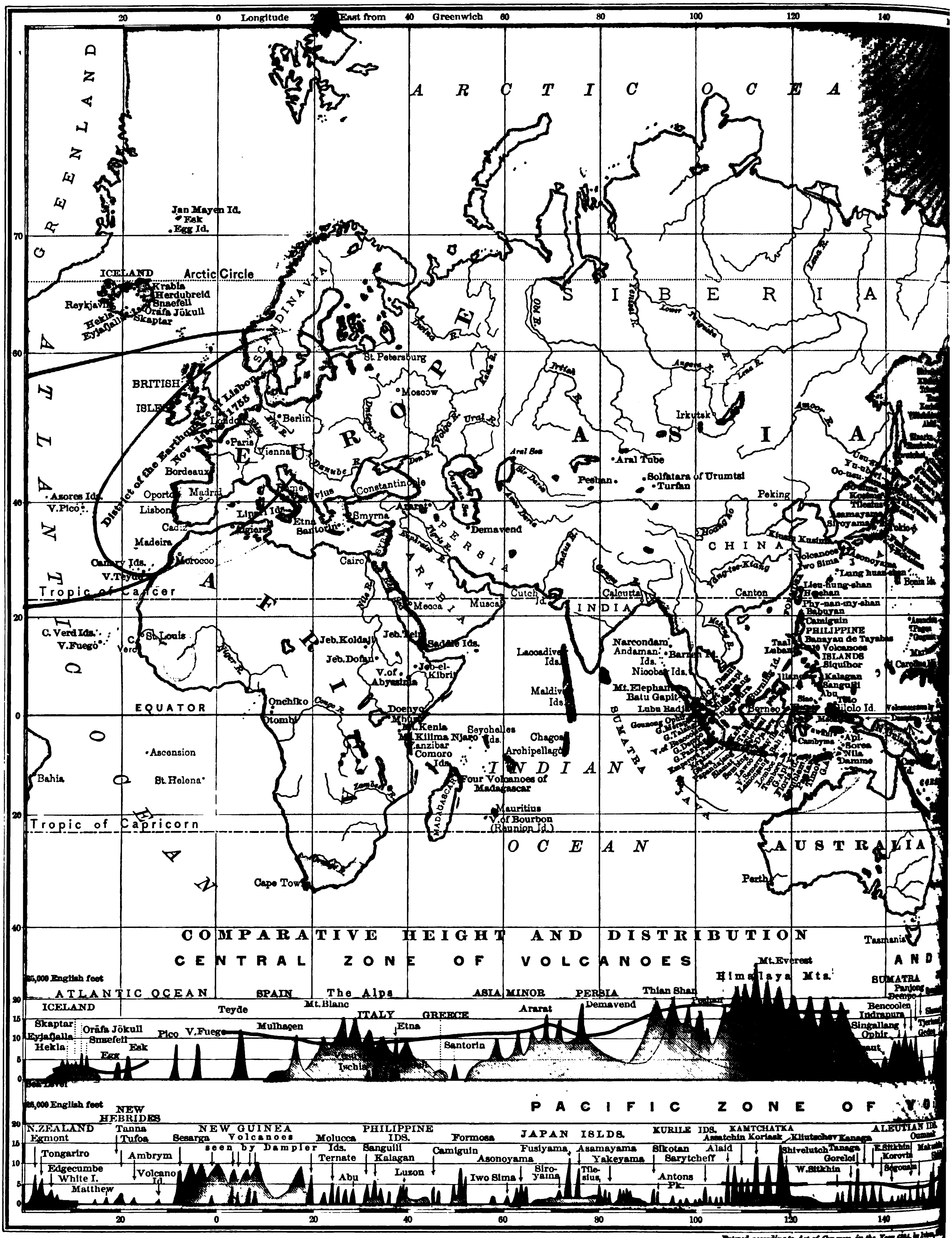
[1] See page 78, I.



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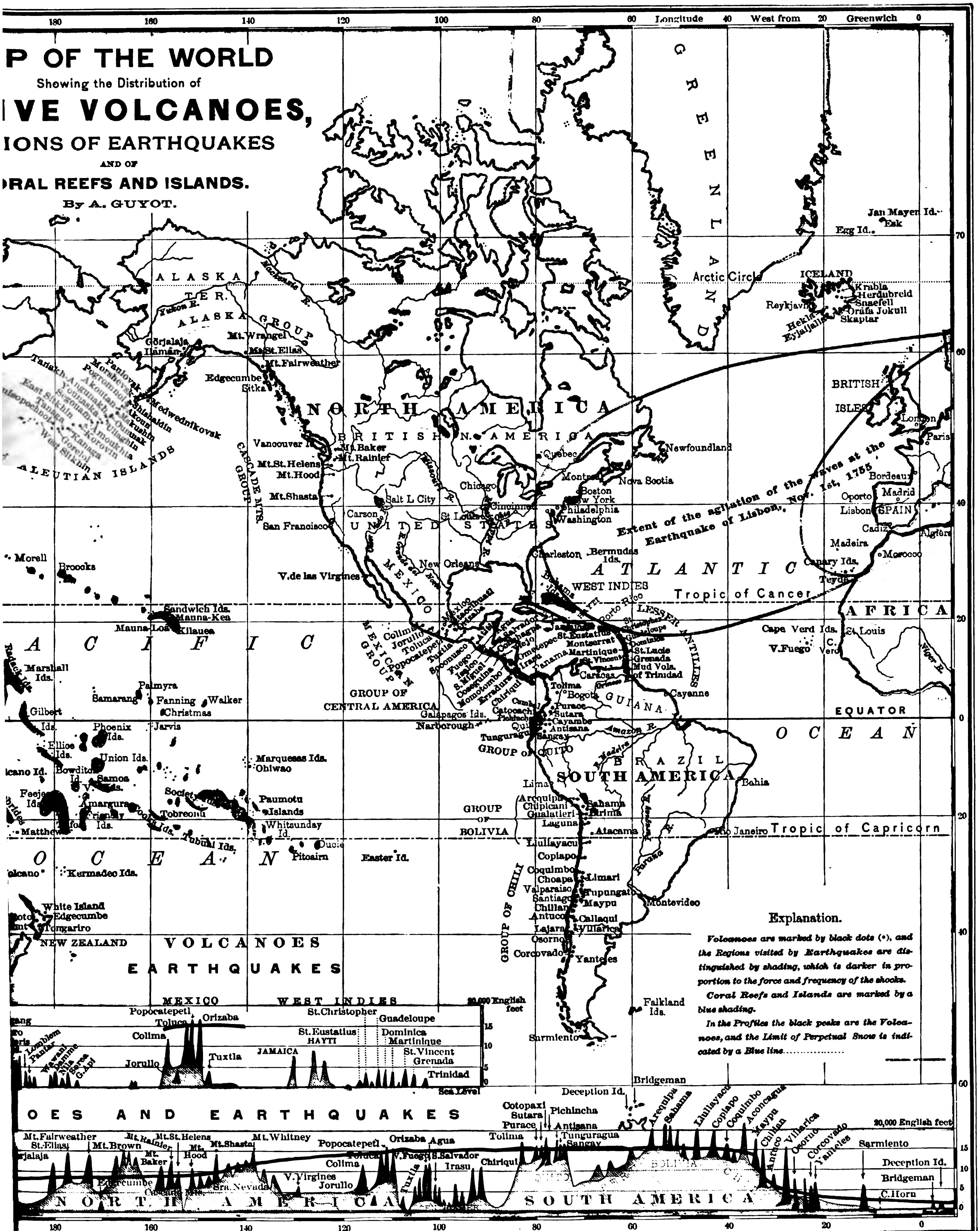

Explanation.

*Volcanoes are marked by black dots (•), and the Regions visited by Earthquakes are distinguished by shading, which is darker in proportion to the force and frequency of the shocks.*

*Coral Reefs and Islands are marked by a blue shading.*

*In the Profiles the black peaks are the Volcanoes, and the Limit of Perpetual Snow is indicated by a Blue line.*

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cooling and contraction of the heated mass enclosed by the hardened outer crust. In this case every difference of pressure upon the Earth's crust, whether arising from atmospheric or astronomical causes, may have a share in the production of earthquakes.

### ANALYSIS OF SECTION X.

**I. Earthquake Phenomena Described.**
- 1. GENERAL DEFINITION.
- 2. EARTHQUAKE OF LISBON DESCRIBED.
  - a. Time and effects.
  - b. Movements of ground.
  - c. Movements of sea.
  - d. Extent of area agitated.

**II. Kinds of Motion.**
- 1. UNDULATORY MOVEMENT.
  - a. Character, and relation to other motions.
  - b. Directions of waves.
  - c. Examples. Linear. Central.
- 2. VERTICAL MOVEMENT. Example.
- 3. ROTARY MOVEMENT. Example.
- 4. VELOCITY OF EARTHQUAKE WAVE.

**III. Duration of Earthquakes.**
- 1. GENERAL STATEMENT.
- 2. EXAMPLES.

**IV. Distribution of Earthquakes.**
- 1. GENERAL FACTS OBSERVED.
  - a. Extent of phenomenon.
  - b. Earthquake areas.
  - c. Earthquake zones.
- 2. ANALOGY OF DISTRIBUTION WITH THAT OF VOLCANOES.
  - Connection of earthquakes with volcanic action.

**V. Relation to Atmospheric and Astronomical Cause.**
- 1. CONNECTION WITH ATMOSPHERIC DISTURBANCES.
- 2. WHAT CONNECTION WITH ASTRONOMICAL CAUSES OBSERVED.

**VI. Theory of Earthquakes.**
- 1. A GENERAL CAUSE NECESSARY. WHY.
  - Where such cause possibly found.

## QUESTIONS ON THE MAP OF VOLCANOES AND EARTHQUAKES.

How are volcanoes indicated on the map? (See *Explanation* in right-hand margin.)

How are the regions which are subject to earthquakes marked?

On what part of the Earth's surface are volcanoes most numerous?

How do North and South America compare in regard to the number of their volcanoes?

What are the principal volcanic groups of South America?

In which are volcanoes most numerous?

What great volcanic groups between South America and the main mass of North America?

What two groups on the Pacific coast north of the Tropic of Cancer?

What are the principal volcanic peaks in the Cascade group?

What group of volcanoes between North America and Asia?

Name the principal volcanic groups of Eastern Asia.

Where are most of these volcanoes situated?

In what direction does the Philippine chain of volcanoes extend?

In what direction does the chain of the Sunda Islands extend?

How do this chain and the Philippine compare in direction at their intersection?

What short chain east of, and parallel to, the Philippine chain?

What group in the midst of the Pacific, in nearly the same latitude?

What celebrated volcano in the Sandwich Islands?

How does the long volcanic chain extending from New Guinea to New Zealand, compare in direction with the adjacent Australian coast?

In what part of this chain are volcanoes most numerous?

What solitary volcano in the eastern part of the Pacific Ocean, near the Tropic of Capricorn?

What islands containing volcanoes, form a long chain extending from Easter Island to the volcanic group of New Guinea.

How does this long volcanic chain compare in direction with the southern coasts of Asia and Europe?

What volcanoes in the northeastern part of the Indian Ocean?

In the southwestern part?

What noted volcanoes in the Mediterranean regions?

What one in Western Asia?

In what part of Africa is a prominent volcanic region? In what part of Asia?

What volcanic islands in the north of Africa?

What volcanic islands in the middle Atlantic, west of Africa?

In what portions of the New World are earthquakes most frequent and violent? In what portions of Europe and Asia? In what Asiatic islands?

What islands in the South Pacific subject to frequent earthquakes? In the Central Pacific?

## REVIEW OF PART I.

NOTE.—The pages to which the questions refer are indicated by figures in the margin.

(Page 1.) What forms the subject of geographical science?

From what points of view may the Earth be studied geographically?

What are the resulting divisions of the science?

(2.) How many are the modes of treatment in the geography of nature?

What are some of the more important problems investigated in physical geography?

How does physical geography differ from geology?

Enumerate the topics discussed in Section I., and the primary divisions of each as shown in the tabular analysis.

How is the Earth related to the Sun and other heavenly bodies?

(3.) What is the comparative importance of the Earth among the heavenly bodies?

What bodies compose the solar system?

Enumerate the topics discussed in Section II., and state, briefly, the substance of each.

How are the primary planets grouped?

How do the two groups compare in size? In density? In distance from the Sun?

To which group does the Earth belong?

What motion is common to the Sun and all the planets?

What other motion have all the planets?

(5.) How does the velocity of revolution vary in the different planets?

The velocity of rotation?

The time of revolution?

What is the position of the axes of the planets in respect to the planes of their orbits?

What is the effect of the inclination of the axis of a planet?

How does the Earth compare with the other planets in its various physical conditions?

Enumerate the topics discussed in Section III., and the subdivisions, both primary and secondary, of each.

(6.) What is the form of the Earth?

The approximate dimensions?

The specific gravity?

Enumerate the topics discussed in Section IV., and give, briefly, the substance of each.

(7.) How do the degrees of longitude compare in length in different latitudes? Why?

Explain the relation of difference of longitude to difference of time.

Enumerate the topics discussed in Section V., and give the substance of each.

(8.) What is a magnet? What properties are exhibited by all magnets?

What property of a magnet is exhibited by the Earth?

What is magnetic declination; and where is there no variation.

Enumerate the topics discussed in Section VI., and the primary subdivisions of each.

(10.) What evidences are there of a high temperature within the Earth?

(11.) How do thermal springs give evidence of internal heat?

Where are the most remarkable geyser regions?

Explain (see page 10) the formation of the geyser.

How are artesian wells supposed to be formed?

(12.) State the results of observations, in wells and mines, on the Earth's temperature.

Describe a volcanic mountain, and the mode of its formation.

Enumerate the topics discussed in Section VII., and give the substance of each.

(13.) On what does the shape of a volcanic cone depend?

What are the chief substances ejected by volcanoes?

What can you say of the amount of materials ejected?

How does the activity of volcanoes vary at different times?

Describe Vesuvius during a period of repose.

(14.) What are the usual premonitions of an eruption? Describe an eruption.

What atmospheric phenomena accompany a violent eruption?

When was the first eruption of Vesuvius in historic time, and what its result?

What contrasts to Vesuvius are presented by other famous volcanoes?

Enumerate the topics discussed in Section VIII., and the primary subdivisions of each.

(15.) Describe the general distribution of volcanoes.

Where are the two great volcanic zones situated?

What are the principal groups in the Pacific zone?

In the transverse central zone?

(16.) What is the primary source of volcanic action?

Enumerate the topics discussed in Section IX., and give the substance of each.

How is volcanic action related to the upheaval of mountain chains?

What are earthquakes?

Describe the great earthquake at Lisbon.

What are the different classes of earthquake movement? How do they compare in violence?

(17.) With what velocity does the earthquake wave move?

How are the most extensive earthquake areas situated?

What coincidence with atmospheric disturbances has been observed?

What general cause may be supposed to give rise to earthquakes?

Enumerate the topics discussed in Section X., and give the substance of each.

# PART II.

# THE LANDS.

## I. — GENERAL ARRANGEMENT OF LAND MASSES.

### I. Geographical Elements of the Earth.

The solid *land*, the liquid *sea*, and their common gaseous envelope, the *atmosphere*, mutually acting upon one another, form the three great geographical elements which, under the influence of the Sun, support life in all its varied forms.

The extent, form, and relative position of the land masses, materially modify climate, and regulate the distribution and development of organic life. Hence the study of these fundamental features of the globe, though apparently elementary, is of primary importance.

The *proportion* of land to water upon the globe is as 27 : 72, the land covering 53,000,000 square miles, the sea 144,000,000.

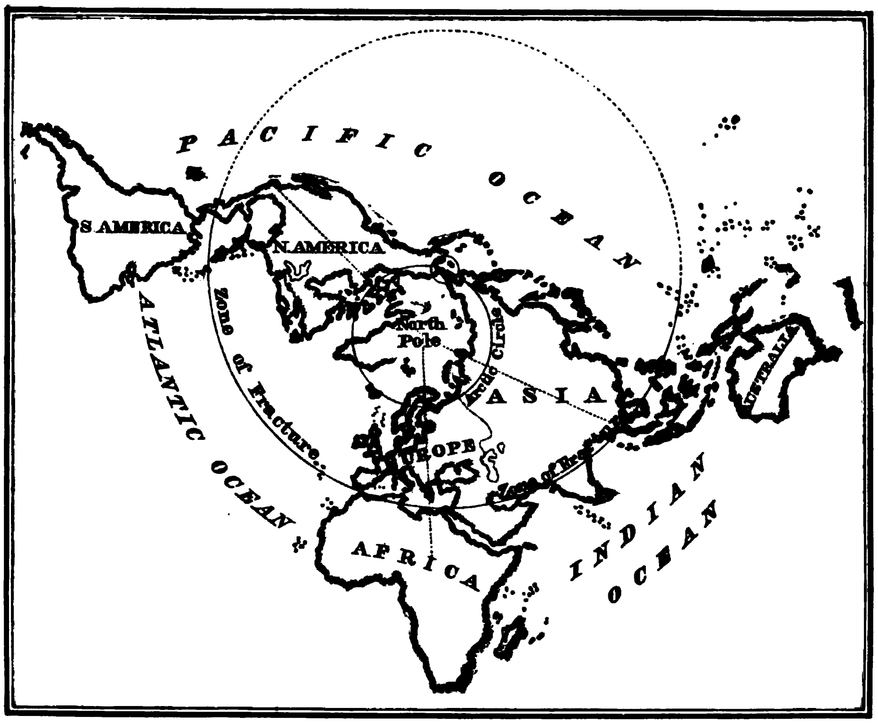


FIG. 1. DIVERGENCE OF LAND MASSES, AND ZONE OF FRACTURE.

### II. The Land Masses.

1. Division. The land is neither concentrated into one vast mass, nor uniformly distributed over the globe.

It consists of six great bodies called *continents*, widely differing in size and form; and a multitude of small fragments called *islands*, which skirt the shores of the continents or dot the broad expanse of the sea.

This *division of the land* into diverse bodies produces a diversity of climate, and promotes a fuller and more perfect development of every order of life.

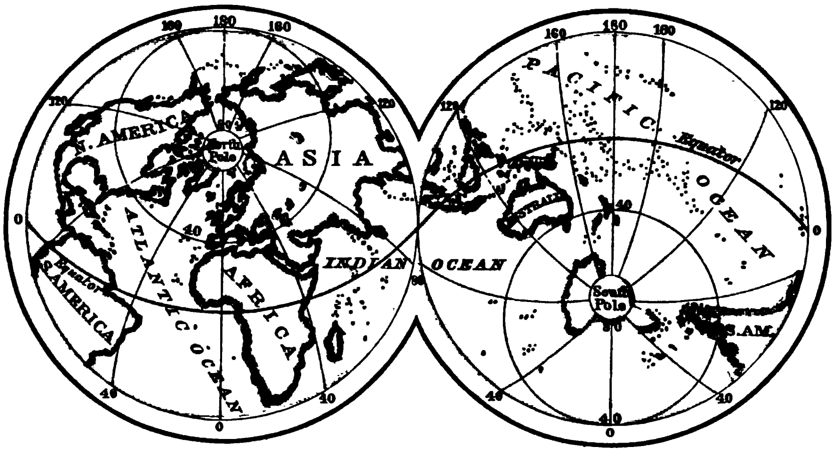


FIG. 2. LAND AND WATER HEMISPHERES.

2. Position on the Globe. The *land masses* are crowded together around the north pole, their northern limits being about the 70th parallel. Thence they extend towards the south, in three vast divergent tracts, terminating in points widely separated one from another, and very distant from the south pole.

The *sea* encircles the south pole, and sends three great arms northward, between the divergent land masses, forming the Pacific, the Atlantic, and the Indian Ocean.

3. Zone of Fracture. Each of the three divergent tracts of land is invaded nearly midway by the ocean, or by great inland seas, from which there results, in each, a belt of broken lands — peninsulas and islands. Within this belt are the great archipelagoes of the East and West Indies, and the peninsulas of southern Asia and Europe.

These regions form part of a broad transverse zone which may properly be designated the central *zone of fracture*. Its position can be traced by describing a circumference upon the globe, from Behring Strait as a centre, with a meridian arc of 80° as a radius.

**Figure 1 exhibits the divergent arrangement of the land masses, and the zone of fracture. The latter passes over the Carribean Sea, in the New World; and the Mediterranean Sea and East Indian Archipelago, in the Old.**

### III. Grand Terrestrial Contrasts.

1. Northern and Southern Worlds. The transverse zone of fracture divides each of the divergent tracts of land into two continental masses, or a pair of continents. Hence there are three northern and three southern continents, forming two groups which present marked contrasts.

The *northern continents* lie near together, and almost wholly within temperate latitudes; the *southern continents*, on the con-

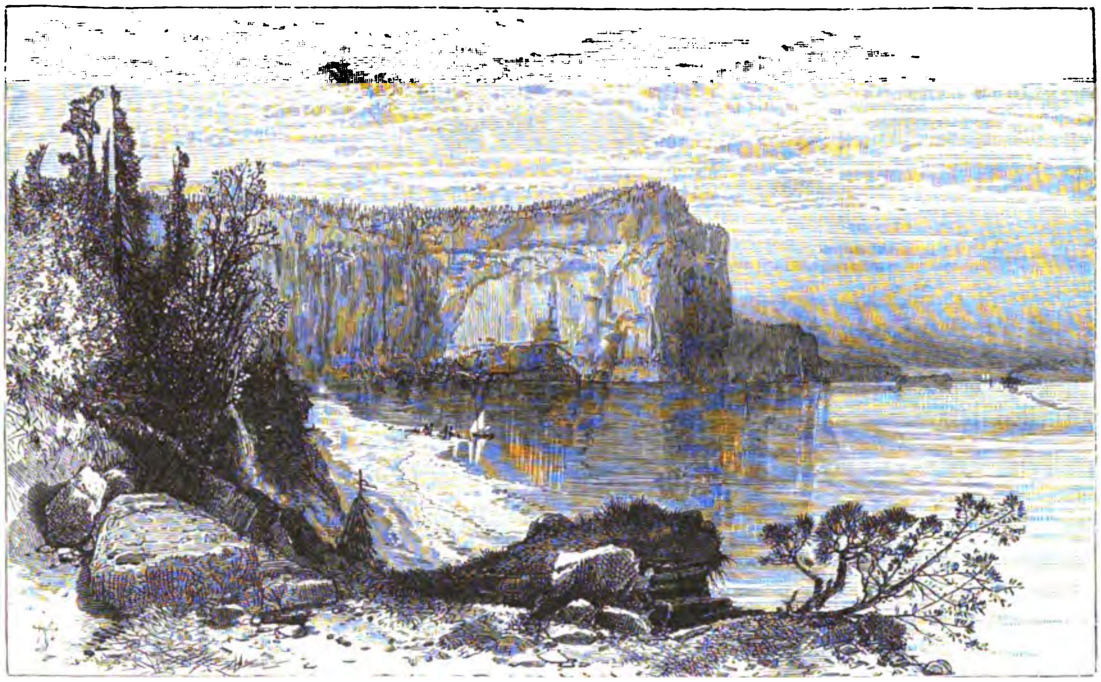
### III. The Mississippi System.

1. The Basin of the Mississippi consists of the three long slopes which form the southern half of the great central depression of the continent — the slope from the Rocky Mountains eastward, from the Appalachian Mountains westward, and from the Height of Land southward.

2. Three great tributaries, each representing one of these slopes, form, by their union, the main stream; namely, the Missouri, much the longest, from the west; the Ohio, contributing the greatest amount of water, from the east; and the upper Mississippi, from the north.

The *channel* of each of these great affluents is fixed by the configuration of the surface. The Mississippi flows along the line in which the inner slopes, from the primary and the secondary highlands of the continent, meet; the Missouri and Ohio lie where these slopes are met by the subordinate one from the height of land. The first, though so much shorter than the Missouri before their confluence, properly gives its name to the system, since it occupies the main or central valley.

Two other tributaries of great length, the Arkansas and Red rivers, together with many minor ones, swell the waters of the main stream, and establish means of intercommunication between all parts of this vast basin.


VIEW ON LAKE SUPERIOR. THE PICTURED ROCKS.

The *western affluents* have the most extensive basins and the longest courses, but they transport comparatively little water; while the eastern contribute a large amount of water from limited areas.

The *Ohio*, whose entire basin lies in the path of the moist southwesterly winds from the Gulf of Mexico, is the largest contributor.

The following table gives the area of drainage, length of course, and average discharge of water per second, of each of the main tributaries of the Mississippi, and of the entire system. The figures are from the "Report upon the Physics and Hydraulics of the Mississippi River, by the U.S. Topographical Engineers."

TABLE OF STREAMS OF THE MISSISSIPPI SYSTEM.

| Rivers. | Area of Basin. | Length in English miles. | Mean Discharge per second. |
|---|---|---|---|
| Missouri . . . . . . | 518,000 Eng. sq. miles. | 2,900 | 120,000 cub. ft. |
| Ohio . . . . . . . . . | 214,000 " " | 1,265 | 158,000 " " |
| Upper Mississippi . . . | 169,000 " " | 1,330 | 105,000 " " |
| Arkansas . . . . . . . | 189,000 " " | 1,514 | 63,000 " " |
| Red . . . . . . . . . | 97,000 " " | 1,200 | 57,000 " " |
| The Smaller Tributaries . | 57,000 " " | – | 172,000 " " |
| Mississippi entire . . . | 1,244,000 " " | 3,184 Miss. proper.<br>4,200 Lower Miss. and Mo. | 675,000 " " |

### IV. St. Lawrence System.

The St. Lawrence, like the upper Mississippi, rises in the Height of Land in the very heart of the continent, its *remote source*, the St. Louis River, being only an inconsiderable stream.

The *real sources* of this noble river are, however, that chain of magnificent lakes, of which it is the only outlet.

The *extent of its basin* — only about two-fifths of that of the Mississippi — is singularly small compared with the magnitude of the stream, and with the volume of water it discharges into the sea, which is said to be more than double that of the Mississippi.

### V. Other Systems.

The *Yukon*, draining the northern extremity of the Pacific highlands, the *Rio Grande del Norte*, draining the southern part of the Rocky Mountains, and the *Columbia* and *Colorado*, draining the central portions of the Pacific slope, complete the list of great rivers in North America. None of these is less than 1,000 miles in length, while the longest, the Yukon, is 2,044 miles long.

The *minor streams* form five groups. The first group drain the short slopes surrounding Hudson Bay; the second, the Atlantic slope of the Appalachian mountains; the third, the short slopes around the Gulf of Mexico.

The fourth group drain the Pacific slopes of the Sierra Nevada and Cascade mountains. The fifth lie in the enclosed basin, between the Sierra Nevada and the Rocky mountains, and discharge into salt lakes, among which the Great Salt Lake of Utah is the largest.

TABLE OF NORTH AMERICAN RIVERS AND LAKES.

| Rivers. | Area of Basin in English sq. miles. | Length of Course in English miles. | Rivers. | Area of Basin in English sq. miles. | Length of Course in English miles. |
|---|---|---|---|---|---|
| Mississippi (Lower & Mo.) | 1,244,000 | 4,200 | Colorado, Texas . . . | 38,000 | 600 |
| Mackenzie . . . . . . | 590,000 | 2,500 | Brazos . . . . . . . . | 34,000 | 650 |
| St. Lawrence . . . . . | 480,000 | 2,384 | Alabama . . . . . . . | 33,000 | 650 |
| Saskatchewan . . . . | 478,000 | 1,515 | St. John . . . . . . . | 26,500 | 450 |
| Columbia . . . . . . | 298,000 | 1,020 | Susquehannah . . . . | 25,000 | 400 |
| Colorado . . . . . . | 257,000 | 1,000 | Hudson . . . . . . . | 12,000 | 330 |
| Rio Grande del Norte . . | 240,000 | 1,500 | Connecticut . . . . . . | 10,600 | 350 |
| Yukon . . . . . . . | 200,000 | 2,044 | Savannah . . . . . . . | 10,000 | 300 |
| Arkansas . . . . . . | 189,000 | 1,500 | | | |

| Lakes. | Area in sq. miles. | Altitude in feet. | Depth in feet. | Lakes. | Area in sq. miles. | Altitude in feet. | Depth in feet. |
|---|---|---|---|---|---|---|---|
| Superior . . . . | 31,400 | 600 | 1,200 | Great Slave Lake . | 8,300 | – | – |
| Michigan . . . . | 25,600 | 574 | 1,000 | Ontario . . . . | 7,300 | 235 | 600 |
| Huron . . . . . | 23,800 | 574 | 1,000 | Nicaragua . . . | 3,500 | – | – |
| Erie . . . . . . | 10,000 | 565 | 80 | Great Salt Lake . | 3,200 | 4,200 | – |
| Great Bear Lake . | 9,300 | 230 | – | Athabasca . . . | 3,200 | 600 | – |
| Winnipeg . . . . | 8,900 | 628 | – | Lake of the Woods, | 500 | 977 | – |

*This table shows* that the four great river systems of the continent belong to the central plains, and those of the second order to the Pacific. The coast rivers, as compared with these, are inconsiderable; and the Gulf rivers, both in area of basin and length of course, exceed those flowing directly into the Atlantic. The *great lakes* are all within the central plains, belonging to the St. Lawrence, the Mackenzie, and the Saskatchewan system.

### ANALYSIS OF SECTION III.

- **I. Influence of Continental Structure.**
  - a. Of position of main axis.
  - b. Of positions of fundamental highlands.
  - c. Of secondary water-shed.
  - d. Of depressed basins.
- **II. Main Water-shed of North America.**
  - a. What constitutes it.
  - b. Primary hydrographical centre.
  - c. Secondary hydrographical centre.
- **III. Mississippi System.**
  - 1. BASIN. HOW CONSTITUTED.
  - 2. THREE GREAT TRIBUTARIES.
    - a. Directions.
    - b. Position of channels.
    - c. Other tributaries.
  - 3. AMOUNT OF WATER TRANSPORTED.
    - a. Western affluents.
    - b. Eastern affluents.
    - c. Table of Mississippi system.
- **IV. St. Lawrence System.**
  - a. Remote source.
  - b. Real source.
  - c. Extent of basin.
- **V. Other Systems.**
  - a. Remaining great rivers.
  - b. Minor streams.
- **VI. Table of North American Rivers.**
  - a. Relative rank of systems.
  - b. Position of lakes.

## IV.—DRAINAGE OF SOUTH AMERICA.

### I. Influence of the Continental Structure.

The *position of the two axes* of the continent, near opposite shores, gives to South America the same general plan of drainage as exists in North America; but the greater *unity of structure* in the former gives rise to a still more extensive combination of streams than in the latter.

Thus it is that South America, though ranking fourth among the continents in size, possesses the most extensive river system of the globe, the Amazon, whose *area* of drainage is 2,300,000 square miles, more than double that of any other system.

*The effect of the extreme inequality of the continental slopes*, is seen in the fact that only mountain torrents enter the Pacific; while three vast systems, including very nearly all the considerable streams of the continent, enter the Atlantic.

Each of the systems is especially connected with one of the great features of the continental structure. The Amazon derives its main waters from the Andes, but receives tributaries from both of the subordinate highlands. The La Plata is the system of the Brazilian table-land, and the Orinoco of the mountain-land of Guiana; but each receives subordinate streams from the Andes.

The *uniformity of surface* in the interior plains, together with their alluvial formation, in marked contrast to the central plains of North America, causes that entire absence of great lakes which is noticeable in South America.

### II. The Amazon System.

1. BASIN. This *basin is composed* of the great eastern slope of the central Andes, and two subordinate regions — the northern slope of the plateau of Brazil, and the southern of the mountain-land of Guiana. The Madeira on the south, and the Rio Negro on the north, mark the intersections of these slopes.

2. SOURCE OF WATERS. The main stream and its greatest tributaries are from the Andes. They drain a continuous arc of mountains nearly 2,000 miles in length, including the highest portions of the system. Streams of great length and volume also flow from the Brazilian plateau, but those from the mountain-land of Guiana are comparatively unimportant.

The position of the Amazon in the continent, and the source whence its waters are derived, correspond to those of the Saskatchewan in North America; but, while the former ranks first among the streams of the earth, the latter is a river of secondary order.

3. THE AMOUNT OF WATER transported by the Amazon system surpasses that of other streams as greatly as does the area of its drainage. The vast basin lies wholly in the latitude of most abundant tropical rains, and no barrier intervenes to exclude from it the wealth of moisture transported westward by the trade winds from the Atlantic.

The *broad estuary*, at the mouth of the river, may justly be compared to a sea of fresh water; and for hundreds of miles from the shore, the turbid yellow stream flows on, distinct from the clearer waters of the surrounding ocean.

### III. Other Systems.

1. The RIO DE LA PLATA basin is similar in position and structure to the Mississippi basin, and very nearly as extensive. It includes the southern portions of the interior plain and the Brazilian plateau, together with the eastern slope of the Andes of Bolivia and Chili. Only secondary tributaries, however, flow from the latter.

The main stream of this system is the Parana; its principal tributaries the Paraguay and Uruguay. The name of Rio de la Plata belongs only to the broad estuary at the mouth of the Parana.

2. THE ORINOCO BASIN corresponds in position and structure to the Mackenzie basin of North America, though its area is considerably less. It includes the eastern slope of the northern Andes, the northern plains, and the main mass of the mountain-land of Guiana; the principal stream coming from the latter, and following its base.

The Orinoco and La Plata basins, however, can hardly be considered as separated from that of the Amazon by regular watersheds. The head waters of the Paraguay, in the La Plata system, mingle with those of the Madeira, during the rainy season, in inundated swamps. The Orinoco in its upper course divides, sending nearly one third of its water to the Amazon system, by the Cassiquiare, a permanent stream comparable in size to the Rhine.

3. MINOR STREAMS. The *San Francisco*, draining a longitudinal valley at the western foot of the secondary continental axis, corresponds to the St. Lawrence in North America. The *Magdalena*, between the ranges at the northern extremity of the Andes, corresponds to the Yukon; and the small *Rio Negro*, draining the southern extremity of the high Andes, to the Rio Grande del Norte.

Thus the similarity in the general plan of structure of North and South America, gives rise to a marked resemblance in the position and combination of their streams.

The only large lakes in South America are Lake Maracaybo (area 5,300 square miles, altitude, sea level) and Lake Titicaca (area 3,500 square miles, altitude 12,850 feet, depth 700 feet).

### IV. Table of South American Rivers.

| RIVERS. | Area of Basin in Eng. sq. miles. | Length of Course in Eng. miles. | RIVERS. | Area of Basin in Eng. sq. miles. | Length of Course in Eng. miles. |
|---|---|---|---|---|---|
| Amazon . . . . . | 2,275,000 | 3,750 | La Plata, or Parana . | 1,242,000 | 2,300 |
| Ucayali . . . . . | 140,000 | 1,400 | Paraguay . . . . | 560,000 | 1,400 |
| Purus . . . . . | 140,000 | 1,500 | Uruguay . . . . | 150,000 | 1,100 |
| Madeira . . . . | 345,000 | 2,200 | Pilcomayo . . . | 75,000 | 950 |
| Tapajos. . . . . | 150,000 | 1,200 | Vermejo . . . . | 50,000 | 600 |
| Xingu . . . . . | 130,000 | 1,500 | Orinoco . . . . . | 340,000 | 1,550 |
| Tocantins . . . . | 270,000 | 1,600 | San Francisco . . . | 250,000 | 1,550 |
| Yapura . . . . . | 80,000 | 1,200 | Magdalena . . . . | 95,700 | 750 |
| Rio Negro . . . . | 280,000 | 1,600 | Rio Negro (southern) | 36,000 | 750 |

### ANALYSIS OF SECTION IV.

**I. Influence of Continental Structure.**
- a. Position of axes.
- b. Unity of structure.
- c. Inequality of continental slopes.
- d. Relation of systems to structural features.
- e. Uniformity of interior plains.

**II. Amazon System.**
- 1. The Basin.
  - a. How constituted.
  - b. Intersection of slopes, how marked.
- 2. Source of Water.
  - Corresponding stream of North America.
- 3. Amount of Water Transported.

**III. Other Systems.**
- 1. La Plata Basin.
  - a. Position and structure.
  - b. Regions included.
  - c. Source of main stream.
- 2. Orinoco Basin.
  - a. Position and structure.
  - b. Regions included.
  - c. Source of main waters.
  - d. The Orinoco and La Plata basins as related to the Amazon basin. Connections.
- 3. Minor Streams.
  - a. San Francisco.
  - b. Magdalena.
  - c. Rio Negro.

**IV. Table of South American Streams.**

## V.—DRAINAGE OF ASIA AND EUROPE.

### I. Eastern Asia.

1. Influence of the Continental Structure. The position of the two axes of Asia, near the centre of the main body of the continent, together with the plateau character of the central depression, gives to this continent a plan of drainage quite opposite to that pervading the New World. The *waters of the central depression* are imprisoned within it by a girdle of snowy mountain chains, and, having no outlet, are carried away by evaporation.

The *exterior slopes*, descending from the central mass towards the four cardinal points, send their waters, in many separate streams, to the adjacent oceans and inland seas. Those upon the same slope are approximately parallel, rarely flowing together. Hence this vast continent does not show such extensive combinations of rivers as distinguish the great interior plains of the New World.

2. Principal Streams. Three great streams—the Obi, the Yenisei, and the Lena—flow northward, through the vast plains of Siberia, into the Arctic Ocean. Three others—the Amoor, the Hoang-Ho, and the Yang-tse-Kiang—descend the eastern slope, through high mountains, valleys, and alluvial plains, to the Pacific. On the southeast two—the Mekong and Irawaddy—flow, between long parallel mountain chains, into the gulfs of Siam and Bengal.

Three on the south, the "sacred streams" from the Himalayas—the Sampu or Brahmapootra, the Ganges, and the Indus—enter the Indian Ocean. Two on the west—the Amoo Daria, and the Sir Daria—entering the Aral Sea, complete the garland of great rivers descending from the central highlands. In the central depression, the Tarim, after a course of 1,700 miles, disappears amid the sands of the desert of East Turkestan, in Lake Lop, whose only outlet is by evaporation.

### II. Western Asia.

Western Asia, with its central table-land of Iran, and its peninsular plateau of Arabia, has but one considerable river system, that of the Euphrates and Tigris, flowing into the Persian Gulf. In the central depression of Iran, from which no water finds its way to the ocean, the Helmund has a course of 800 miles, and loses itself in Lake Hamoon, in the swamps of Seistan, as the Tarim does in Lake Lop.

### III. Europe.

1. Separate Hydrographical Centres. High Europe, on the southwest, a mountain-land with great peninsulas, and low Europe, on the northeast, a region of vast plains—each has, like Asia, a hydrographical centre from which streams radiate in every direction. The snow-crowned Alps in the former, and the low Valdai Hills in the latter, form these centres.

2. High Europe. Four streams—the Rhine, the Danube, the Rhône, and the Po—drain the entire system of the Alps. The Rhine alone takes its course directly to the ocean, forcing its way to the sea through narrow and picturesque defiles, across the secondary highlands which surround the Alps. The others flow parallel with the mountain mass, collecting nearly all the Alpine waters, and finally entering inland seas.

Numerous streams of lesser magnitude flow from the secondary highlands to the adjacent seas, with a general direction towards the northwest imparted by the slope of the continent in that direction.

In each of the three main divisions of High Europe (see page 36, Topic II.) are four principal streams. The western has the Garonne and the Loire, from the central plateau of France, and the Pyrenees; the Seine and the Meuse, from the plateau of Langres. (See map, page 37.)

The central division has the Weser and the Elbe, from the inclosed basins; the Oder and the Vistula, from the outer slope of the marginal highlands.

The eastern has the Theiss and the Aluta, from the plateau of Transylvania, with the Pruth and the Sereth, from the Carpathian Mountains, all of which enter the Danube.

The *course* of the principal streams of High Europe affords a striking illustration of the fact, that the direction of the flowing waters is governed by the general slope of the mass elevations of the continent, and not by the mountain ranges. The latter, indeed, form but trifling obstacles in the path of streams, often causing no more than a small deviation from their general course. A slight swell operates in the same manner, and often produces as great an effect, as a range of mountains. (See *Coast Swell*, on map, page 37.)

From the Alps the land descends gradually northward to the Baltic Sea, eastward to the Black Sea, and westward to the

Atlantic Ocean. The *Danube*, rising in the Black Forest Mountains, follows the general eastward slope, passing, through transverse gaps, a number of mountain ranges lying directly across its course.

The *Rhine*, rising in the central Alps, follows the slope of the highlands towards the north. It crosses the Swiss Alps and the Jura, by transverse valleys, forming Lake Constance between them; then descends the longitudinal valley between the Vosges and Black Forest Mountains, rounds the northern terminus of the former, and crosses, nearly at right angles, the plateau of the lower Rhine.

VIEW ON THE RHINE.

The head waters of the *Rhône* cross the Swiss Alps and the Jura, descending the westward slope; but, turned aside by the high border of the massive plateau of central France, the stream descends the longitudinal valley between the Cévennes and the Western Alps, to the Mediterranean.

In like manner the *Weser* and the *Elbe*, rising in the interior basins north of the Alps, traverse the secondary continental axis and the swells which intervene between it and the northern seas; while the *Oder* and *Vistula* cross the swells only. Each departs from its original northwesterly course in crossing these barriers, but returns to it as soon as the obstacle is passed.

3. Low Europe. The European plain, unlike the great interior plains of the New World, is highest in the centre, where the Valdai Plateau is about 800 feet in altitude, with hills of 1,100 feet.

Hence its streams, instead of being combined into a few great systems, are dispersed in separate courses, descending the slopes from the interior, towards the four cardinal points. These divergent streams all enter the four inland seas, which border upon the great European plain and form its only outlets.

Low Europe, with more extended plains, has on the whole longer rivers than High Europe. But here, also, the central swell suffices to prevent a combination of the flowing waters into one great system like that of the Mississippi.

It is worthy of remark, that the longest streams of Europe, and those draining the largest areas, are nearly all directed towards the vast depression which separates that continent from Asia.

4. The PENINSULAS have only subordinate streams. The longest are those of Spain, which descend from the northeastern highlands, near the Mediterranean shores, to the Atlantic Ocean.

In the Scandinavian Peninsula the streams mainly enter the Baltic, the fiords, due to the submergence of the valleys, taking the place of rivers on the Atlantic slope. In the transverse valleys, on the eastern slope of the mountains, are many beautiful Alpine lakes, some of which are of considerable size.

## IV. Tables of Rivers and Lakes of Asia-Europe.

| RIVERS OF ASIA. | Area of Basin in Eng. sq. miles. | Length of Course in Eng. miles. | RIVERS OF ASIA. | Area of Basin in Eng. sq. miles. | Length of Course in Eng. miles. |
|---|---|---|---|---|---|
| Obi | 1,250,000 | 3,000 | Indus | 402,000 | 1,850 |
| Yenisei | 1,040,000 | 3,400 | Mekong | 400,000 | 2,500 |
| Yang-tse-Kiang | 950,000 | 3,320 | Euphrates | 255,000 | 1,750 |
| Lena | 800,000 | 2,700 | Tarim | 235,000 | 1,160 |
| Amoor | 786,000 | 2,650 | Amoo Daria | 220,000 | 1,260 |
| Hoang-ho | 714,000 | 2,800 | Irawaddy | 140,000 | 1,200 |
| Brahmapootra | 450,000 | 2,300 | Sir Daria | 100,000 | 1,200 |
| Ganges | 416,000 | 1,600 | Helmund | 80,000 | 800 |
| RIVERS OF HIGH EUROPE. | | | RIVERS OF LOW EUROPE. | | |
| Danube | 311,000 | 1,800 | Volga | 600,000 | 2,000 |
| Rhine | 90,000 | 880 | Dneiper | 180,000 | 1,120 |
| Vistula | 68,900 | 550 | Don | 170,000 | 1,100 |
| Elbe | 59,500 | 800 | Dwina | 130,000 | 1,000 |
| Loire | 52,000 | 550 | Ural | 106,000 | 970 |
| Rhône | 37,400 | 550 | Petchora | 100,000 | 1,000 |
| Po | 31,200 | 450 | Duna | 44,000 | 600 |

| LAKES OF ASIA. | Area in sq.miles | Altitude in feet. | Depth. |
|---|---|---|---|
| Caspian Sea | 132,000 | -85 | 2,700 |
| Aral Sea | 26,400 | 26 | 200 |
| Baikal Lake, East Siberia | 15,200 | 1,280 | 3,000 |
| Balkhash, West Siberia | 6,400 | 500 | 60 |
| Tengri-nor, Thibet | 3,500 | - | - |
| Tong-ting, China | 2,300 | - | - |
| Koko-nor, Mongolia | 2,000 | - | - |
| Urumia, Armenia | 1,700 | 4,350 | 50 |
| Kossogol, Mongolia | 1,500 | 5,520 | - |
| Van, Armenia | 1,414 | 5,115 | - |
| Dead Sea, Palestine | 500 | -1,286 | 1,300 |
| Sir-i-kol, Pamir | 40 | 15,600 | - |

| LAKES OF EUROPE. | Area in sq.miles | Altitude in feet. | Depth. |
|---|---|---|---|
| Ladoga, Russia | 6,900 | 50 | - |
| Onega, " | 4,900 | 237 | - |
| Wener, Sweden | 2,300 | 143 | - |
| Wetter, " | 800 | 289 | 400 |
| Maelar, " | 320 | 6 | - |
| Balaton, Hungary | 255 | 469 | 38 |
| Hielmar, Sweden | 202 | 76 | - |
| Leman, Geneva, Switzerland | 240 | 1,226 | 980 |
| Constance, Switzerland | 190 | 1,287 | 1,027 |
| Garda | 140 | 237 | 950 |
| Maggiore, Italy | 70 | 685 | 2,620 |
| Como, Italy | 59 | 697 | 1,930 |

## ANALYSIS OF SECTION V.

**I. Eastern Asia.**

1. Influence of Continental Structure.
   - a. Position of axes.
   - b. Waters of central depression.
   - c. Waters of exterior slopes.

2. **Principal Streams.**
    a. Of northern, eastern, and southeastern slopes.
    b. Of southern and western slopes.
    c. Of central depression.

**II. Western Asia.**

    a. Principal system. Stream of central depression.

**III. Europe.**

1. **Separate Hydrographical Centres.**
2. **High Europe.**
    a. Four Alpine systems.
    b. Secondary systems of High Europe.
    c. Truth illustrated by course of these streams. Effect of mountain ranges and swells.
    d. Course of Danube. Rhine. Rhône.
    e. Course of secondary streams.
3. **Low Europe.**
    a. Hydrographical centre. Result. Course of rivers.
    b. Streams compared with those of High Europe.

**IV. Tables of Rivers and Lakes.**

## VI.—DRAINAGE OF AFRICA AND AUSTRALIA.

### I. Africa.

1. Influence of Structure. Africa having, like the American continents, its axes near opposite shores, has its flowing waters combined in the interior of the continent. Five principal systems—the Nile, the Niger, the Congo, the Zambesi, and the Orange—embrace nearly all the flowing waters of the continent; and all but the last derive their water wholly from the tropical region, between 20° south and 16° north latitude. Each is especially connected with one of the primary regions of the continental structure.

2. The Nile, draining the west slope of the main axis, is the most characteristic as well as the most celebrated of African streams. Its *main sources* are in great lakes, near the equator, from 3,000 to 4,000 feet above the level of the sea; but, in its middle course, it receives the waters of eastern Soudan and Abyssinia. This part of the course is characterized by the famous "Cataracts of the Nile," the last of which occurs at Assuan, at the entrance of the stream into Egypt.

Below the Atbara the Nile traverses a rainless district 900 miles in breadth, within which, in a course of 1,400 miles from the Mediterranean, it does not receive a single tributary; and *its valley* is a narrow belt of verdure in the midst of a burning desert.

The fertility of this narrow valley is due to alluvial soil accumulated during the periodic overflows of the river. This wonderful *inundation* in a rainless region, so mysterious to the ancient world, is explained by the fact that, though its lower course is in temperate latitudes, all the sources of the Nile lie within the region of abundant periodical rains. These fall copiously on the sources of the White Nile about the time of the equinoxes, and in Abyssinia a little later.

The Abyssinian rains, being nearer the mouth, cause a first rise, which reaches Egypt about the middle of June. This is soon followed, and increased to the maximum, by the rising waters of the White Nile; and in August and September the flood is at its height. By the middle of October it begins to abate; in November the water has receded sufficiently to permit the sowing of the seed in the fresh mud. In December all the valley is green with growing crops, and the harvests follow in quick succession.

3. Other Systems. The *Niger* drains the Kong plateau. Starting in the west, from the highest portion, it descends successive terraces to the interior depression; then turning southward, and reaching the sea through a break in the mountains, it forms a delta far surpassing in extent the famous delta of the Nile.

The *Congo*, draining the equatorial portion of the central depression, is the Amazon of Africa. It discharges, into the Atlantic, a volume of water fully three times that of the Mississippi; and its powerful current is perceptible in the sea, scores of miles from the mouth.

The *Zambesi* drains the southern part of the central depression, and enters the Indian Ocean. In its middle course is the celebrated Victoria Fall, discovered by Dr. Livingstone, and said to rival in majesty and beauty the cataract of Niagara.

The *Orange* River drains the extreme southern plateau, in which the continental axes meet. Nearly its entire course lies through a table-land from 4,000 to 5,000 feet in altitude.

### II. Australia.

No continent has so few rivers as Australia. The *Murray*, with its great tributaries, the Darling and the Lachlan, forms the only river system worthy of the name. Owing to the great irregularity of the rains, most other rivers have no permanent existence, but are transformed, in seasons of drought, into a series of disconnected, shallow pools or lakes.

### III. Table of African and Australian Rivers and Lakes.

| Rivers. | Basin in English sq. miles. | Course in English miles. | Lakes. | Area in sq. miles. | Altitude in feet. | Lakes. | Area in sq. miles. | Altitude in feet. |
|---|---|---|---|---|---|---|---|---|
| Nile . . . . | 1,425,000 | 3,834 | Albert, Africa, | 26,000 | 2,700 | Moero, Africa, | 1,800 | 3,000 |
| Congo . . . . | 860,000 | 2,610 | Victoria, " | 21,500 | 4,200 | Tzana, " | 1,000 | 6,000 |
| Niger . . . . | 800,000 | 2,585 | Tchad, " | 15,000 | 800 | Ngami, " | 300 | 2,800 |
| Zambesi . . . | 900,000 | 1,027 | Tanganyika, A. | 9,200 | 2,800 | Eyre, Aust'a, | 3,000 | 70 |
| Orange . . . | 446,000 | 1,000 | Nyassa, Africa, | 8,000 | 1,300 | Gairdner, " | 2,400 | 366 |
| Murray, Aust. . | 500,000 | 1,400 | Bangweolo, " | 5,000 | 4,000 | Torrens, " | 2,600 | – |

### IV. Conclusion.

The distribution of river systems shows how closely, in each continent, the drainage depends upon the general plan of structure.

Farther, we observe that the Atlantic and Arctic oceans, toward which all the long continental slopes are turned (see page 42, IX., and map, page 63), receive, either directly or through inland seas, three-fourths of all the continental waters, including the greatest streams of the globe. The Pacific and Indian oceans, covering nearly half of the Earth's surface, receive but the remaining fourth; and among these only the three streams of Eastern Asia hold the first rank in regard to length of course and extent of basin.

### ANALYSIS OF SECTION VI.

**I. Africa.**

1. **Influence of Structure.**
    a. Position of axes.
    b. Source and connections of systems.
2. **Nile System.**
    a. Region drained by it.
    b. Main sources. Accessions in middle course.
    c. Peculiarities of lower course.
    d. Valley, source of fertility.
    e. Inundations. Cause. Progress. Termination.
3. **Other African Systems.**
    a. Niger. Region drained by it. Course.
    b. Congo. Zambesi.
    c. Orange.

**II. Australia.**

    a. Comparative number of streams. Principal system.
    b. Character of other streams.

**III. Table of Rivers.**

**IV. Conclusion.**

# THE SEA.

## I.—INTRODUCTION.

### I. Sea Water.

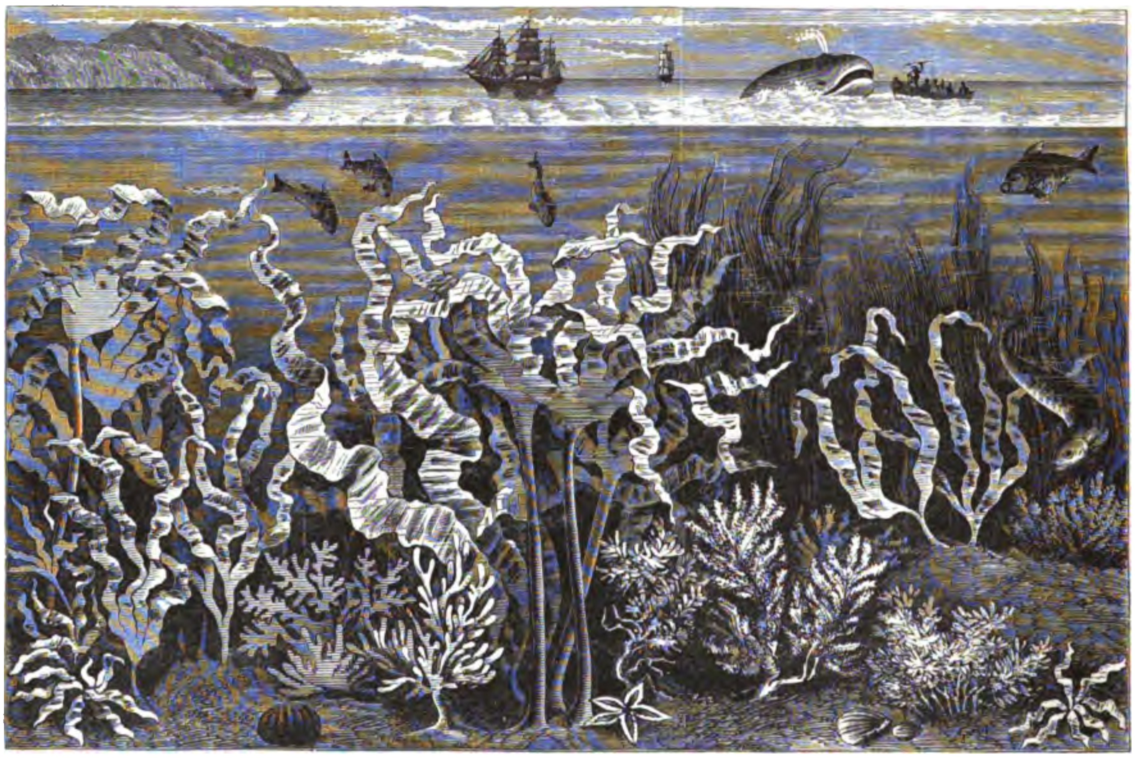
1. Its Composition. The water of the sea *contains* in solution a large amount of common salt (chloride of sodium), and smaller proportions of sulphate and carbonate of lime, magnesia, potash, iodine, and some other substances. It is estimated that they constitute about one-thirtieth of the entire weight of sea water.

*In the open ocean* the composition of the water is nearly uniform, though about 20° north latitude, and 16° south, there is a slightly greater proportion of saline matter than elsewhere.

Some *enclosed arms of the sea*, in or near tropical regions—like the Mediterranean and the Red Sea—evaporating more water than they receive by rivers, and having in consequence a constant influx of sea water, are more salt than the ocean.

Others, like the Black and Baltic seas, receiving more water by rivers than they evaporate, and discharging the excess into the sea, are less salt than the ocean.

2. The temperature of the ocean, *at and near the surface*, varies with the latitude, from an average of 80° Fahr. within the tropics, to near the freezing point in the polar regions, where ice is to be found in the sea at all seasons of the year.



SUBMARINE LIFE IN THE NORTHERN SEAS.

*Below a certain depth*, which varies with the latitude, the temperature is nearly uniform, at from 33½° to 35° Fahr., about equal to the average temperature of the surface waters in latitude 60°.

In lower latitudes, as the climate becomes warmer, this low temperature is found at constantly increasing depths; until, at the equator, it is reached only about 10,000 feet below the surface. Towards the poles, also, where the climate is colder, the line of uniform temperature rapidly sinks; and in latitude 70° it is found at the depth of about 4,000 feet.

Thus it appears that within 60° of the equator the deep waters are colder than the surface, while beyond that latitude they are warmer.

The *salt of the ocean* tends to preserve its liquid condition at low temperatures. Sea water freezes only when the temperature is reduced to 26½°, while the freezing point of fresh water is 32° Fahr.

### II. Marine Life.

The ocean supports an inconceivable variety of *animal life*. Its inhabitants vary in size, from the gigantic whale to animals too small to be perceived by the unaided eye; and in organization, from the mammal to the formless, jelly-like mass, floating upon the surface of the water.

It is, perhaps, not equally rich in *vegetable life;* but plants in great variety, some of which are exceedingly beautiful in form and color, are found, both attached to rocks in the shallow waters adjacent to the shores, and floating in mid ocean. Immense fields of sea weed, covering thousands of square miles, occur in those portions of the ocean not disturbed by the general currents. The most remarkable of these is the *Sargasso Sea*, near the Tropic of Cancer in the Atlantic Ocean.

### III. Bottom of the Sea.

The bottom of the sea, as far as known, is less irregular than the surface of the continents, but its variations of level are on a much grander scale.

It is convex, like the surface of the sea, being a vast area of the Earth's crust slightly depressed below the regular curve of the sphere; while the continents are smaller areas, elevated somewhat above this curve.

On these depressions, the waters, originally covering the entire surface of the sphere, have collected, in obedience to the law of gravity, filling up the irregularities in the spherical outline, and forming the oceans.

This convexity of the sea bottom is clearly illustrated by the *Sections of the Atlantic Basin*, page 60.

#### ANALYSIS OF SECTION I.

- **I. Sea Water.**
  - 1. Its Composition.
    - a. Substances in solution.
    - b. Waters in open ocean.
    - c. Waters in enclosed seas.
  - 2. Temperature.
    - a. At and near the surface.
    - b. Temperature of deep waters.
    - c. Temperature of depths towards the equator.
    - d. Temperature of depths towards the poles.
    - e. Deep waters compared with surface.
    - f. Freezing point of sea water.
- **II. Marine Life.**
  - a. Animal life.
  - b. Vegetable life.
  - c. Examples of marine vegetation.
- **III. Bottom of Sea.**
  - a. Nature of its surface.
  - b. Relation to spherical outline.
  - c. Why covered with waters of globe.

## II. — THE OCEANS.

### I. The Basins of the Oceans.

1. Their Separation. The waters of the sea are separated by the lands into *three great oceans*, which are the counterparts of the land masses. The Pacific, the Atlantic, and the Indian Ocean, correspond to three pairs of continents in which the lands are grouped (see p. 21, II.), and separate them one from another.

The Atlantic and the Pacific are subdivided, each having a northern and a southern basin, corresponding to the northern and the southern continents. The Indian Ocean has only a southern basin; but the vast depression between Asia and Europe, in the bottom of which lie the Caspian and Aral seas, may be considered as, in a certain sense, its complement.

The *Arctic Ocean* is properly a continuation of the Atlantic; but, surrounded as it is by the coasts of the three northern continents, it has a physiognomy of its own. The *Antarctic*, also, is not properly a separate ocean, but is the common centre from which the three great basins radiate.

2. Their Forms and Sizes. *Each of the three* great oceans is broadest at the south, and gradually narrows towards the north; hence their general figure is the opposite of that of the continental masses.

The *Pacific* is oval in outline, and broadly open at the south; but it is nearly closed at the north, the opposite shores converging so that the narrow passage of Behring Straits connects this ocean with the Arctic.

This vast basin contains more than half of the waters of the entire sea. Its extent, its compact form, and the direction of its greatest elongation from southeast to northwest, makes it the counterpart of Asia-Europe, the dominant mass of the Old World.

The *Atlantic* basin, which has only about one-half the area of the Pacific, has been likened by Humboldt to a long valley, with approximately parallel sides. This is the only basin widely open at the north; and, stretching from pole to pole, it forms the only complete channel for the interchange of polar and equatorial waters. By its narrow, slender form, and its direction from north to south, it forms the counterpart of the New World.

The *Indian* Ocean, which has a triangular outline, has no communication with the northern waters. It finds its counterpart in Africa, like itself compact in outline, and almost destitute of projecting members.

3. Their Branches. The three great ocean basins differ in regard to the position and character of the branches, by which the coasts of the continents are indented, each being distinguished by a particular class of coast waters.

Coast waters *may be classified*, according to their form and their position in respect to the adjacent lands, as inland seas, border seas, and gulfs or bays.

The first lie within the general figure of the continent, being enclosed by peninsulas, as the Baltic Sea; or between adjacent continents, as the Mediterranean and Red seas. (See map, pages 28, 29.)

The second lie without the continental figure, and are separated from the main ocean by islands, as the Caribbean Sea. The third are simple bends in the coast line, without separation from the ocean basin, as the Gulf of Bengal.

The *Atlantic* is the most branching of the oceans. It has all the forms of coast waters just described, but is especially distinguished by the number and great size of its inland seas. Two of these, the Mediterranean Sea and the Gulf of Mexico, lie in the warm regions; and two, Hudson Bay and the Baltic Sea, in colder latitudes.

The broader seas are represented by the Caribbean Sea, within the tropics and the Gulf of St. Lawrence and the North Sea in temperate latitudes. The Gulf of Guinea, and the Bay of Biscay, are examples of the third class of coast waters in the Atlantic.

The *Pacific* is particularly rich in vast border seas, a continuous series of which lines the Asiatic and Australian coasts. Among these are the Behring Sea, enclosed by the peninsula of Alaska and the Aleutian Islands; Okhotsk Sea, enclosed by Kamchatka and the Kurile Islands; the Sea of Japan, and the North and South China seas; and the Arafura, Coral, and New Zealand seas, on the Australian Coast.

Only two inland seas of considerable size — the Gulf of California in North America, and the Yellow Sea in Asia — mark this entire basin.

The *Indian* Ocean is characterized by gulfs, two of which form the entire extension of the basin; namely, the Gulf of Bengal, and the Arabian Sea. It has also two inland seas of considerable extent, the Red Sea and the Persian Gulf, isolating the peninsula of Arabia from the adjacent continents; but border seas are wholly wanting in the Indian Ocean.

4. Their Islands. The *Pacific* is far richer than the other oceans in both continental and oceanic islands. The most extensive continental archipelago on the globe is formed by the multitude of islands lying between Asia and Australia. Successive series of continental islands skirt the entire eastern coast of Asia and Australia; and nowhere is found a parallel to the multitude of oceanic islands which are spread over the central portions of this basin. (See Map, page 18.)

The *Atlantic* possesses — in the Antilles, the British Isles, and the islands of the Mediterranean — continental archipelagoes of great importance; but its oceanic islands are limited to the groups of the Bermuda, Azores, Madeira, Canary, and Cape Verd Islands, with St. Helena and a few other isolated volcanic islands.

The *Indian* Ocean has comparatively few islands of either class. Madagascar, Ceylon, and Socotora, represent the continental islands; the Laccadives and Maldives, with here and there a few volcanic islands, as Bourbon and Mauritius, make up the oceanic.

### II. The Beds of the Ocean.

1. Extent of our Knowledge. Little is known, in detail, in regard to the conformation of the bottom of the sea. But numerous soundings, both in shallow shore waters and in the deep sea, have given us an approximate idea of the nature of the beds of the Atlantic Ocean, the Mediterranean Sea, the Indian Ocean, and the Red Sea.

2. The Atlantic Bed. The Atlantic basin is, in general, deeper on the side of the New World. The deepest portions, so far as known, form a great trough, in three parts, which are severally parallel to the eastern shore of North America and the northern and eastern shores of South America.

The bed of the North Atlantic seems to consist of *two parallel valleys* — the western about 18,000 feet in average depth, the eastern about 13,000 — separated by a swell less than 10,000 feet deep. (See Fig. 25.) Both valleys become less deep towards the north, but are still distinguishable in the so-called "Telegraph Plateau," between Newfoundland and Ireland. (See Fig. 26.)

In the latitude of Iceland, whose volcanic mass rises from the northern terminus of the dividing swell, the eastern valley is obliterated, the depth of the sea between this island and the European shore scarcely averaging 1,500 feet. The western valley preserves a depth of 8,000 or 9,000 feet as far as Greenland, where it divides, its two branches extending to the Arctic, on opposite sides of Greenland.

The accompanying profiles show, in fathoms, the depths of the Atlantic in equatorial regions (Fig. 25), where the dividing swell is distinctly perceptible; and along the line of the survey for the first Atlantic cable (Fig. 26), where, though less apparent, it still exists.

*Near the continents* the sea is often shallow, the bottom seeming to be only an extension, by gentle slopes, of the adjacent lands.

Along the American shores, in the latitude of New York, the depth, for a distance of more than 100 miles, is less than 600 feet; then suddenly the bed descends, by a steep slope, to the depth of 6,000 or 9,000 feet. After a comparatively narrow interval, a second terrace descends to the main basin, from 15,000 to 18,000 feet deep.

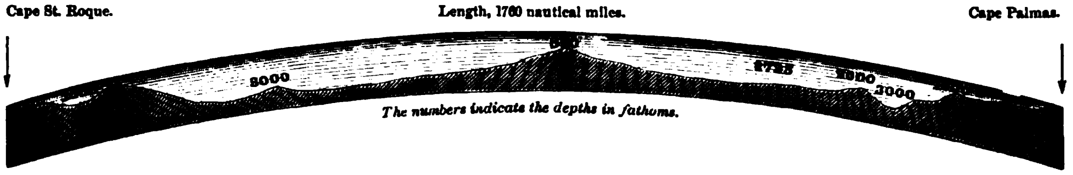

Cape St. Roque.
Length, 1760 nautical miles.
Cape Palmas.
8000
1800
3000
The numbers indicate the depths in fathoms.

FIG. 25. SECTION OF THE ATLANTIC BASIN FROM CAPE ST. ROQUE, BRAZIL, TO CAPE PALMAS, WESTERN AFRICA.

These *regular variations of level*, and the absence of any oceanic islands other than the volcanic and coral islands, disprove the idea, often advanced, that the bed of the oceans is like the surface of a submerged continent, covered with mountain chains and valleys. It seems far more uniform, extensive plains and huge table-lands being its predominating features. Mountain chains are found only near the continents, as parts of the continental structure; and, when reaching above the surface of the sea, they form chains of continental islands.

3. THE PACIFIC AND INDIAN OCEANS. The *Indian Ocean*, — according to soundings made in laying telegraphic cables, from Aden to Bombay, and from Madras to the Malay peninsula,—is quite similar to the Atlantic in the general features of its bed.

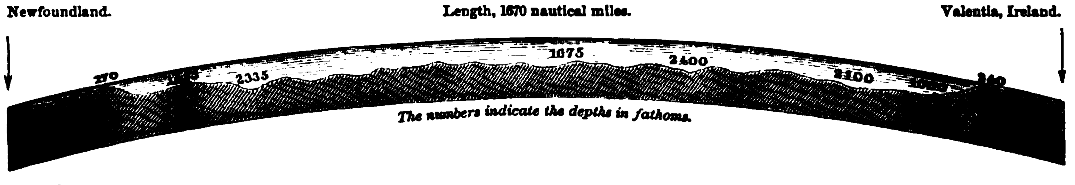

Newfoundland.
Length, 1670 nautical miles.
Valentia, Ireland.
2335
1675
2400
2100
The numbers indicate the depths in fathoms.

FIG. 25. SECTION OF THE ATLANTIC BASIN FROM NEWFOUNDLAND TO VALENTIA ISLAND, ON THE LINE OF THE TELEGRAPH CABLES.

A regular valley, having an average depth of 12,000 feet, lies between Africa and India, its eastern margin being about 200 miles from Bombay, whence a submarine plateau, but a few hundred feet deep, extends to the peninsula.

East of India is a similar valley from 12,000 to 14,000 feet deep. It terminates, near the shores of Sumatra, in a submarine plateau, less than 250 feet below the surface, which forms the base of the islands in the great Indian Archipelago, between Asia and Australia.

The chain of coral islands, — the Laccadives, the Maldives, and the Chagos Archipelago (see map, page 18), — extending southward through the central part of the Indian Ocean, seems to indicate the presence of a submarine dividing ridge in this basin, similar to that separating the two valleys of the Atlantic.

Occasional soundings in the southwestern part of this ocean, indicate depths equal to the maximum in the Atlantic basin.

The *bed of the Pacific* is much less known than that of the Atlantic and Indian oceans. In the absence of soundings, of which few have been made, its average depth has been calculated from the velocity of the tide-wave and earthquake waves crossing it, which depends upon the depth of the basin in which the waves move.

Prof. Bache, late Superintendent of the United States Coast Survey, estimates, in this way, the depth between Japan and California at from 12,000 to 14,000 feet. A calculation by Prof. Hochstetter, based on the movement of the waves raised by the great earthquake of 1868, gives 11,500 feet as the depth of the sea between the South American coast and the Chatham Islands, east of New Zealand. The central part of the South Pacific basin, however, is probably much deeper than this.

4. INLAND AND BORDER SEAS. These enclosed basins belong to the structure of the continents, rather than to the oceans. All are of slight depth, except those lying within the transverse zone of fracture;[1] and even those are shallow in comparison with the great basins with which they are connected, as is apparent from the depths given below.

The *Gulf of Mexico* is from 5,000 to 7,000 feet in depth. The deepest part of the *Caribbean Sea*, on a line connecting Porto Rico and Costa Rica, averages 7,000 feet, and near the latter it reaches a depth of 14,000; but the ocean, immediately outside of the Lesser Antilles, is more than 18,000 feet deep.

The *Mediterranean* is divided into two basins, by a rocky isthmus, from 50 to 500 feet below the surface, lying between Sicily and Cape Bon, in Africa. The western basin is over 9,000 feet in depth, and comparatively uniform; while the eastern is more irregular, varying from 6,000 near the centre, to 13,000 feet, south of the Ionian Islands. The *Red Sea* has an irregular bottom, with an average depth of 3,000 feet, but in some places it reaches 6,000.

The *Baltic Sea*, being a simple depression in the great European plain, is but a few hundred feet deep. In the North Sea, the depth averages 300 feet, and rarely exceeds 600. The continent is here prolonged in the form of a submarine plain, whose highest portions form the British Isles. (See page 38.)

The *Border Seas of Asia*, lying within the chain of continental islands, are only a few hundred feet in depth, while immediately without those islands, abrupt slopes descend to the great depths of the Pacific basin.

5. THE GREATEST DEPTHS thus far found in the ocean basins have been reported from the South Atlantic. Captain James Ross reports a sounding, west of St. Helena, of 27,000 feet, without touching bottom. Captain Denham and Captain Parker report, severally, 46,000 and 50,000 feet, west of the island of Tristan da Cuñha; but, owing to the difficulty of obtaining accurate soundings in great depths, these figures can hardly be accepted as conclusive.

Observations thus far made justify the conclusion that the greatest depths of the sea are from 25,000 to 30,000 feet, about equivalent to the greatest heights upon the continents.

But, rightly to understand the magnitude of these features of relief, it must be remembered that mountain tops are but isolated points, much above the general level of the mass of the emerged lands; while the greatest depths of the oceans are, doubtless, common to extensive surfaces, which are the counterparts of the continental plains of the table-lands.

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[1] See page 21, Topic II., 3.

### ANALYSIS OF SECTION II.

- **I. Ocean Basins.**
  - 1. Their Separation.
    - a. Three great basins.
      - Pacific, Atlantic, Indian.
    - b. Arctic basin.
    - c. Antarctic basin.
  - 2. Form and Size.
    - a. Common feature.
    - b. Pacific basin.
      - Form. Amount of water.
      - Resemblance to Old World.
    - c. Atlantic basin.
      - Form. Extent.
      - Resemblance to New World.
    - d. Basin of Indian Ocean.
  - 3. Extensions on Continental Coasts.
    - a. How classified.
      - Inland seas.
      - Border seas.
      - Gulfs and bays.
    - b. Atlantic.
      - Characteristic coast basins.
      - Other forms of coast basins.
    - c. Pacific.
    - d. Indian.
  - 4. Islands.
    - a. Pacific. Relative number. Examples.
    - b. Atlantic. Relative number. Examples.
    - c. Indian. Relative number. Examples.
- **II. Ocean Beds.**
  - 1. Extent of our Knowledge of them.
  - 2. Atlantic Bed.
    - a. Of what consisting.
      - Depth of valleys and dividing swell.
      - Change of level northward.
    - b. Depth of shores and successive terraces.
    - c. Conclusion from observed variations of bed.
  - 3. Beds of Indian and Pacific Oceans.
    - a. Indian Ocean.
      - Resemblance to Atlantic bed.
      - Bed between Africa and India.
      - Bed east of India.
      - Other parts of bed.
    - b. Pacific bed.
      - Mode of ascertaining its depth.
      - Results of calculations.
  - 4. Inland and Border Seas.
    - a. General character as to depth.
    - b. Gulf of Mexico and Caribbean Sea.
    - c. Mediterranean. Red Sea.
    - d. Baltic.
    - e. North Sea.
    - f. Border seas of Asia.
  - 5. Greatest Ocean Depths.
    - a. Where supposed to be.
    - b. Depths reported.
    - c. Reported figures to be regarded how.

## III.—WAVES AND TIDES.

### I. Oceanic Movements.

The waters of the sea are subject to various kinds of motion, due both to atmospheric and astronomical causes. Chief among them are waves, tides, and marine currents.

### II. Waves.

*Waves* are the alternate rise and fall of successive ridges of water. They result from a disturbance of the equilibrium of the surface waters, by the action of the wind, and affect the sea only to a moderate depth.

*Waves vary* in height, extent, and rapidity of progress, according to the force of the wind, the depth of the water, and the extent of the basin in which they occur. They are much larger, and advance more rapidly, in the open sea than in inland basins.

The *advance of the wave* is the communication of the wave movement to successive portions of the sea; and not, to any considerable extent, except in shallows, an onward movement of the water itself. Thus a body floating upon the surface of the sea may be seen repeatedly rising and falling with the waves, with but a slight change of position.

When waves, advancing towards the shore, reach the shallows, the motion is retarded at the bottom by friction; and the top, moving on without support, curls over and breaks in foam upon the beach; or, in very shallow seas, it may break at a considerable distance from the shore.

After the wind, which disturbed the surface, has subsided, the water continues to undulate with a gentle motion, called the *swell*. This seldom ceases entirely before a fresh storm arouses the waves anew.

### III. Tides.

1. Tides are movements similar in character to waves, but differing in their cause, extent, and the regularity of their occurrence.

Tides are caused by the action of the Sun and Moon upon the Earth; they affect, therefore, the ocean to its greatest depths, and throughout its entire extent; and they occur with unvarying regularity, the water, in every part of the ocean, rising and falling alternately through periods of about six hours each. Each period is followed by an interval of a few moments, during which the water remains at the level it has just attained.

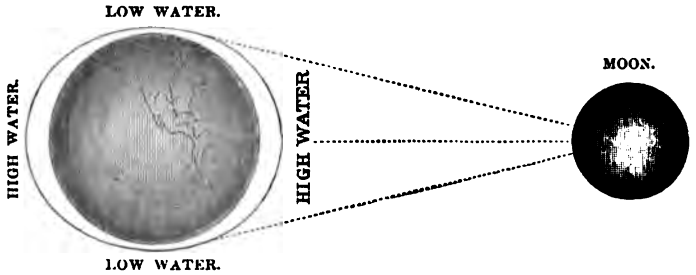


FIG. 27. PRODUCTION OF TIDAL WAVE.

The period of rising water is called *flood tide*, that of receding water, *ebb tide*. The level attained at the close of flood tide is called *high water*, or high tide; and that at the close of ebb tide, *low water*. The *interval* between two consecutive high tides or low tides is twelve hours and twenty-six minutes; hence high water, or low water, occurs about fifty-two minutes later each successive day.

2. Mode of Production of Tides. The *Moon*, notwithstanding its smaller mass, has, on account of its greater nearness to the Earth, an influence in the production of the tides which is more than double that of the Sun (as 100 to 30). The solar tides, being so much less marked, and chiefly merged in or overpowered by the lunar tides, are of secondary importance. The phenomena of the tides must, therefore, be explained mainly by reference to the latter.

*Tidal Waves.* The Moon attracts both the land and the sea; but the particles of the latter being free to move, the waters are drawn towards the attracting body; and, where its influence is most powerful, are lifted up above the normal curve of the surface of the sea.

Thus is formed a vast swell, or *tide wave*, upon the hemisphere turned towards the Moon. The flowing of the more distant waters towards the crest of this wave, causes, on each side of it, a depression of the surface, or low water, which occurs about 90° from the line of high water. (See Fig. 27.)

On the opposite side of the Earth the equilibrium of the sea is equally disturbed, and the same cause produces a second wave, the formation of which is explained as follows: the waters most distant from the attracting body being least affected by it, their weight is somewhat lessened, and they are less attracted towards the centre of the Earth than those on the sides. To restore the equilibrium, the waters on the sides, which exert a greater pressure, tend to move towards the region of least attraction; and their accumulation there raises the surface of the sea slightly above its normal level, producing the second, or counter wave.

Two *areas of high* water, therefore, occur simultaneously upon the Earth, 180° distant from each other, the one under the Moon, and the other on the opposite side of the globe.

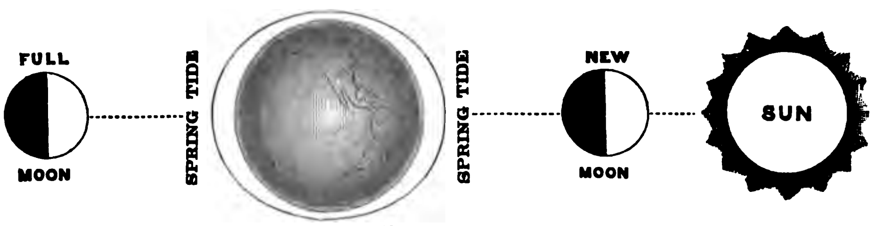


FIG. 28. SPRING TIDES.

Two *areas of low* water occur at the same time, midway between those of high water. Owing to the rotation of the Earth upon its axis, bringing all longitudes successively under and opposite that Moon, this permanent system of waves and troughs travels from east to west over every part of the sea. This occasions the regular succession of rising and falling waters, at equal intervals of time, occurring along all coasts, and known to us as the tides.

3. SPRING TIDES. The attraction of the Sun causes a similar, though less strongly marked, system of four daily tides. As the relative positions of the Earth, the Sun, and the Moon are constantly changing, the solar and lunar tides do not usually coincide. Twice a month, however, at new and full Moon, the three bodies are in a line (as shown in Fig. 28).

At these periods, the Sun and Moon act together; and an unusually high water is produced which is the sum of the solar and the lunar high tide. This is called the *spring tide.* Low water at this period is correspondingly lower than at any other, as high water is higher.

At the first and third quarters of the Moon, the three bodies are so situated relatively to one another (see Fig. 29), that the attractive power of the Sun upon the Earth is exerted at right angles to that of the Moon, thus diminishing the effect of the latter. High water is then below, and low water above, its ordinary level. These are the *neap tides.*

The highest tides occur when the luminaries are nearest, and pass most nearly vertically on the place of observation. The highest of the spring tides occur in March, some time before the vernal, and in September, some time after the autumnal equinox, when the Sun, being vertical at the Equator, and the Moon nearest to the Earth, the equatorial, parent wave is highest. Thus the tides have daily, monthly, and annual periods.

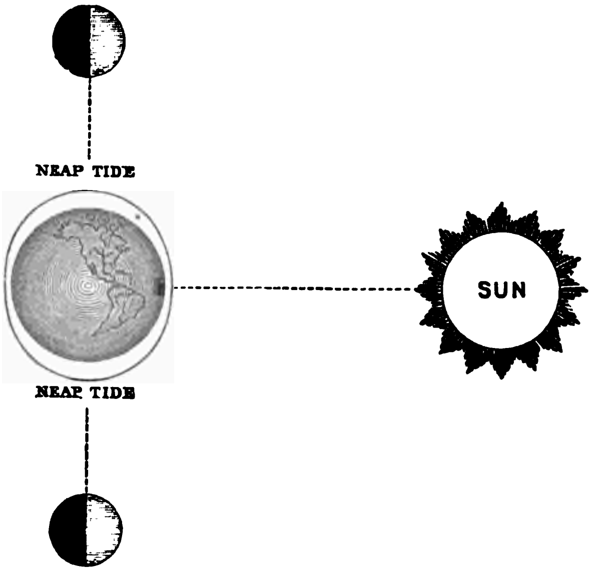


FIG. 29. NEAP TIDES.

## IV. Course of Tidal Waves.

1. INTRODUCTION. If the ocean covered the whole Earth with a uniform depth of water, the tidal waves, with their long crests extending from north to south, would follow the apparent course of the Moon, passing from east to west entirely around the globe. They would be highest in the equatorial regions, and would there move with the velocity of more than 1,000 miles an hour.

The *continents*, which divide the sea into three great basins, oppose the passage of the tidal wave, and it is subjected to great modifications in each ocean.

The *velocity* with which the wave advances depends upon the size and form of the ocean in which it moves, the depth of the water, and the absence of obstacles to its progress. The southern half of the Pacific presents the most favorable conditions; and there is formed what might be called the parent tidal wave, which, entering the Indian and Atlantic oceans, seems to control their tides.

The *Map of Co-tidal Lines*, or simultaneous tides, on page 63, shows the successive positions and directions of the crest of the tidal wave, at intervals of one hour. Each line passes through places having high water at the same hour, the hours being marked on the lines in Roman numerals. The more rapidly and regularly the wave advances, the farther apart and more nearly parallel are the co-tidal lines which exhibit its position at successive hours.

2. TIDAL WAVE OF THE PACIFIC. The *Parent wave*, which originates in the central and southern Pacific, moves on most swiftly in the broad, deep, and unobstructed basin lying south of the Tropic of Capricorn. There, also, it preserves its normal direction westward, and its crest extends nearly north and south.

In the equatorial Pacific its progress is obstructed by the numerous oceanic islands; and, reaching the shallow seas of the great Indian Archipelago (see page 60, Topic III.), it becomes exceedingly slow and irregular. (See *Map of Co-tidal Lines.*)

In the northeastern portion of this basin, the tidal wave is deflected northward and eastward. The deflected wave strikes the American shores, between California and Alaska, at the same hours at which the direct wave strikes the Asiatic shores, between Kamchatka and Japan. A reflected wave also starts in the longitude of the Galapagos Islands; and, advancing eastward and southward along the South American coasts, it meets the tide wave from the south Atlantic at Cape Horn.

### QUESTIONS ON THE MAP OF CO-TIDAL LINES.

NOTE. — The co-tidal lines are numbered from I. to XII. inclusive, corresponding with the divisions of the dial. By observing the numbers on the lines, at given places, one learns the number of hours required for the wave to pass from the one to the other. For example, the line at the Sandwich Islands is numbered II., while that at Sitka, on the American coast, is X. This shows that the latter place has high tide eight hours later than the former.

What part of the North American coast has high water at the same hour with the Sandwich Islands? How many hours between high water at the Sandwich Islands and at New Zealand? (See note above.) How much of the American coast has high water at the same hour with San Francisco?

How long is the tidal wave in passing from the southern point of Kamchatka to the southern point of the Japan Islands? How long is the tidal wave in passing from the Galapagos Islands, across the Pacific, to Kamchatka and New Zealand?

How long from the Galapagos Islands to the southern extremity of South America? How long from the Sandwich Islands northward to the southern coast of Alaska?

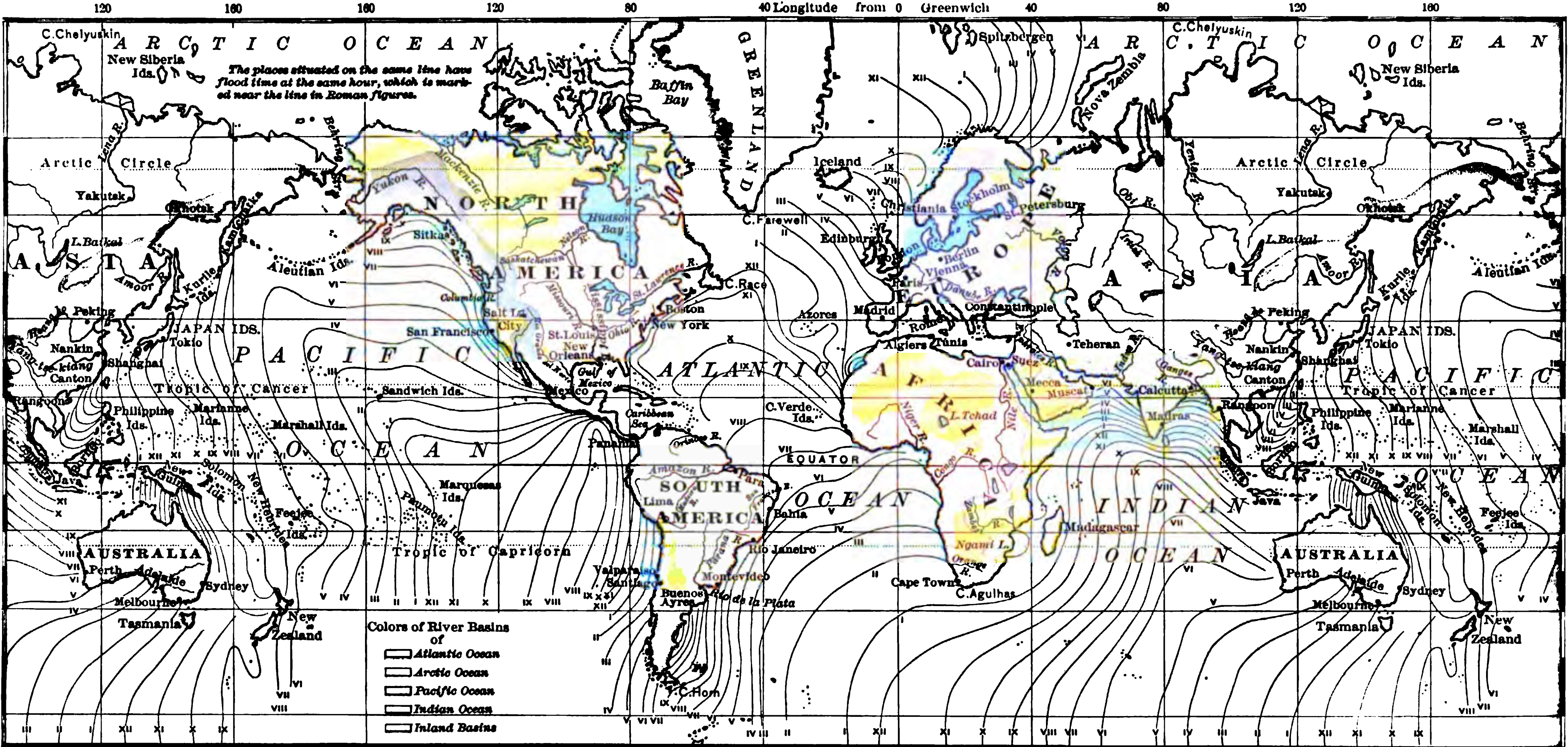
In what direction does the tidal wave advance through the middle and northern part of the Atlantic Ocean? What places have high tide at the same hour with Rio Janeiro?

How long is the tidal wave in passing from Rio Janeiro to Cape Race?

What portions of the North American coast have high tide at the same hour with New York?

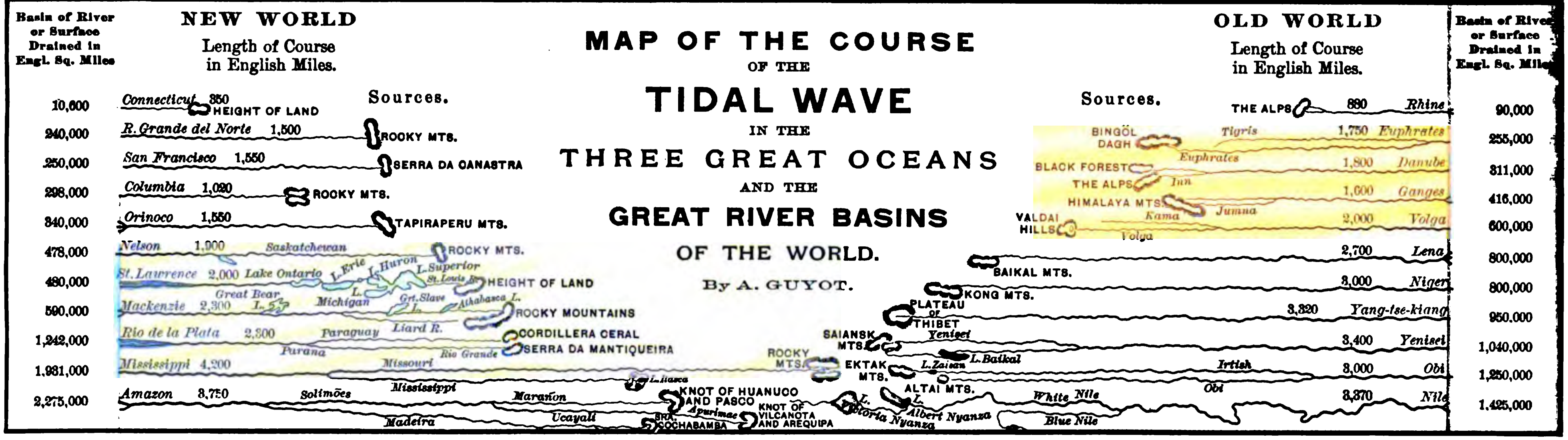
How long is the tidal wave in passing from New Zealand, through the Indian and Atlantic Oceans, to Iceland? How long in passing from New Zealand to Muscat, in Arabia?

What direction does the tidal wave take in the eastern half of the Indian Ocean?



# MAP OF THE COURSE
OF THE
# TIDAL WAVE
IN THE
# THREE GREAT OCEANS
AND THE
# GREAT RIVER BASINS
# OF THE WORLD.

By A. GUYOT.



## NEW WORLD

| Basin of River or Surface Drained in Engl. Sq. Miles | River | Length of Course in English Miles. |
|---|---|---|
| 10,600 | Connecticut | 350 |
| 240,000 | R. Grande del Norte | 1,500 |
| 250,000 | San Francisco | 1,550 |
| 298,000 | Columbia | 1,020 |
| 340,000 | Orinoco | 1,550 |
| 478,000 | Nelson | 1,900 |
| 480,000 | St. Lawrence | 2,000 |
| 590,000 | Mackenzie | 2,300 |
| 1,242,000 | Rio de la Plata | 2,300 |
| 1,931,000 | Mississippi | 4,200 |
| 2,275,000 | Amazon | 3,750 |

## OLD WORLD

| River | Length of Course in English Miles. | Basin of River or Surface Drained in Engl. Sq. Miles |
|---|---|---|
| Rhine | 880 | 90,000 |
| Euphrates | 1,750 | 255,000 |
| Danube | 1,800 | 311,000 |
| Ganges | 1,600 | 416,000 |
| Volga | 2,000 | 600,000 |
| Lena | 2,700 | 800,000 |
| Niger | 3,000 | 800,000 |
| Yang-tse-kiang | 3,320 | 950,000 |
| Yenisei | 3,400 | 1,040,000 |
| Obi | 3,000 | 1,250,000 |
| Nile | 3,370 | 1,425,000 |

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3. Tides of the Indian and Atlantic Oceans. The tides of the *Indian* and *Atlantic* oceans seem to be either overpowered by, or merged into, the great wave generated in the south Pacific.

This wave advances rapidly through the deep waters of these basins; but it is greatly retarded in the northern portions of the Indian Ocean. Muscat, near the northern extremity of the Arabian Sea, has high water at the same hour as Rio Janeiro on the western shores of the Atlantic.

In the middle and south Atlantic the tide wave advances northwestward; in the northern part it moves towards the northeast, following, in both cases, the direction of the narrow ocean basin.

The course of the tidal wave on the coast of the British Isles, illustrates forcibly its *retardation* in shallow and narrow arms of the sea.

The main wave of the north Atlantic advances from Brest, on the western coast of France, to Bergen, on the coast of Norway, in four hours. The branch entering the English Channel has, during the same time, only reached Southampton, and that in the Irish Sea has arrived at Dublin.

The main wave, entering the North Sea from the north, descends slowly along the coasts of Scotland and England; and finally meets the branch from the Channel, which, having passed the Strait of Dover, advances along the coasts of Holland and Germany. (See Fig. 30.)

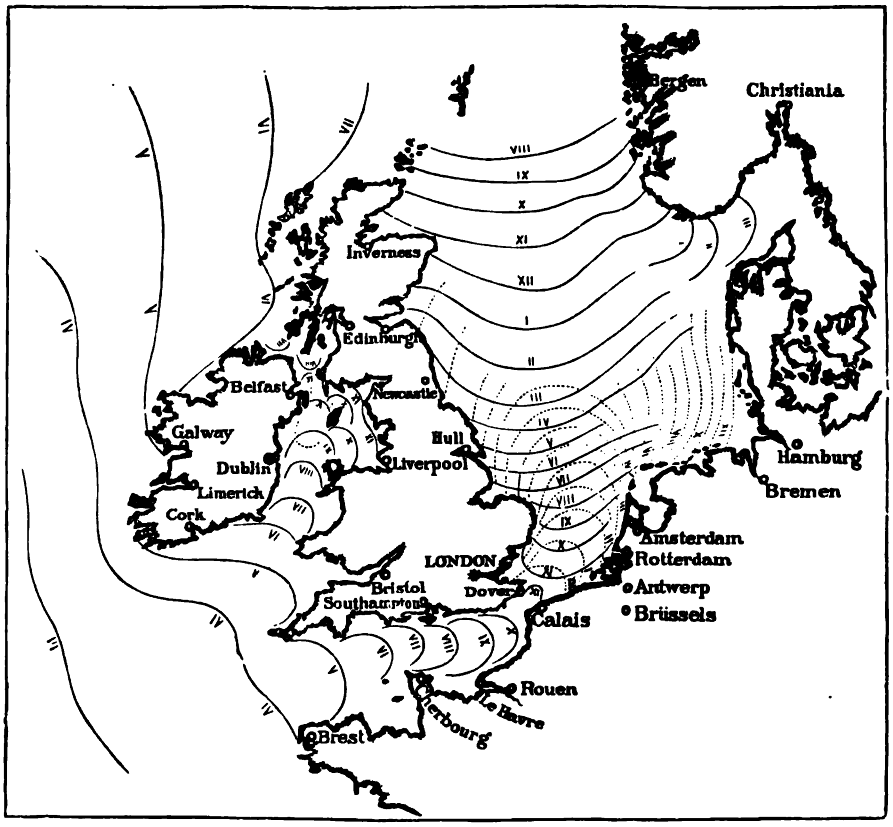

FIG. 30. CO-TIDAL LINES OF BRITISH ISLES.

## V. Height of Tides.

1. Variations in Level. The height of the tide depends on local circumstances. In the midst of the Pacific it is scarcely more than two feet, which may be considered its *normal level*. But when dashing against the land, or forced into deep gulfs and estuaries, the accumulating tide waters sometimes reach a great height.

On the eastern *coast of North America*, the average rise of the tide is from nine to twelve feet. At the entrance to the Bay of Fundy, however, it rises eighteen feet, while at the head of that bay it reaches 60, and in the highest spring tides, even 70 feet. At Bristol, in England, the spring tides rise to 40 feet; and at St. Malo, on the south coast of the English Channel, they reach 50 feet.

2. Effects. Differences in level, produced by high tides, cause currents which vary in force and direction with the condition of the tide, producing, in some cases, dangerous whirlpools. The famous *Maelstrom*, off the coast of Norway, is but a tidal current, which rushes with great violence between two of the Lofoden Islands, causing a whirling motion in the water which is reversed at each ebb and flow of the tide.

Such is, also, the famous whirlpool of *Charybdis*, in the Strait of Messina, and many others of less note. The powerful currents of *Hell Gate*, in the passage from Long Island Sound to New York Bay, are due to a similar cause, high water occurring at different hours in the bay and in the west end of the sound.

1. Bore. In estuaries into which great rivers flow, the resistance offered by the current of the stream to the entrance of the tide, produces a huge wave called the *Bore*, which, like a moving wall of water, advances with great rapidity and a deep roaring noise up the stream to the limit of tide water. The Hoogly, a mouth of the Ganges, the Tsien-tang in China, and the Amazon, afford the most remarkable examples of this phenomenon. The bore of the Tsien-tang rises thirty feet in height, and travels at the rate of twenty-five miles an hour. In the Amazon five bores, each about fifteen feet in height, may sometimes be seen rushing up the river one after the other within the space of 200 miles.

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## ANALYSIS OF SECTION III.

**I. Oceanic Movements.**
- a. Causes of movement in sea water.
- b. Classes of movements.

**II. Waves.**
- a. Description of wave movement.
- b. Cause. Variation in waves.
- c. Advance of waves. Swell.

**III. Tides.**
- 1. Phenomenon Described.
  - a. Kind of motion.
  - b. Difference between tides and waves.
  - c. Periods of tide. Flood. Ebb. High water. Low water.
  - d. Interval between two consecutive high tides.
  - e. Hour of high water on successive days.
- 2. Mode of Production of Tides.
  - a. Comparative influence of Moon and Sun.
  - b. Production of tidal wave under Moon.
  - c. Production of tidal wave on opposite side of globe.
  - d. Areas of simultaneous high water.
  - e. Areas of simultaneous low water.
  - f. Advance of tidal system around globe.
- 3. Spring Tides and Neap Tides.
  - a. Want of coincidence in lunar and solar tides.
  - b. Spring tides, when and how formed, high water, low water.
  - c. Neap tides, when, how formed, high water, low water.
  - d. Highest spring tides. Lowest neap tides.

**IV. Course of Tidal Wave.**
- 1. Introduction.
  - a. Course in case a uniform ocean covered the globe.
  - b. Influence of continents on course.
  - c. Regularity and velocity of motion.
  - d. Explanation of map of co-tidal lines.
- 2. Tidal Wave of Pacific.
  - a. Course of parent or primary tide wave.
  - b. Tidal wave in equatorial Pacific.
- 3. Tidal Wave of Indian and Atlantic Oceans.
  - a. Relation to Pacific tide wave.
  - b. Progress in deep waters.
  - c. Retardation.
  - d. Course around British Isles.

**V. Height of Tide.**
- 1. Variations of Level.
  - a. Height depends on what.
  - b. Normal level.
  - c. High water on North American coast. Exceptions
  - d. Spring tides in Bristol and English Channel.
- 2. Results of Differences of Level.
- 3. Bore — how formed. Examples.

## IV.—MARINE CURRENTS.

### I. General Circulation.

1. The Ocean Currents are vast rivers in the sea, which move on steadily through water comparatively at rest, and are often different from the latter in color and temperature. Some are hundreds of miles broad, thousands of feet deep, and have a course embracing the larger part of the ocean in which they move. Currents exist, not only at the surface, but in the deep waters, where their course is frequently in a different direction from, sometimes even opposite to, that of the surface currents.

2. Equatorial Currents. Within and near the tropics the waters, under the influence of the constant trade winds (see page 77, Topic III.), advance westward around the globe, forming a vast *Equatorial Current* 50° or more in breadth.

Reaching the eastern shores of the continents in each ocean, this great current divides, one part turning northward and the other southward. Advancing towards the poles, these branches swerve gradually eastward; and, reaching the middle latitudes, they cross the ocean, striking the western shores of the continents. Finally, a part at least of the water returns to the equatorial regions, while the remainder continues its course towards the poles.

Thus is formed, on each side of the equator, a vast elliptical circuit of moving waters, occupying the entire breadth of the ocean basins, and extending over the tropical and middle latitudes. In the centre is a broad expanse of quiet water, which is covered, to a large extent, with sea-weed, forming the so-called Sargasso Seas.

The *main causes* of these vast movements in the ocean are found in the winds, the excessive evaporation within the tropics which tends to lower the level of the water there, and the differing temperatures of polar and equatorial regions. The cold waters of the higher latitudes, being heavier, tend constantly to flow into the warmer waters of the equatorial seas; and the latter, being displaced by the former, flow away as surface currents towards the poles.

3. Two series of currents, of opposite character, pervade the sea in high latitudes,—the *cold*, flowing from the polar regions towards the equatorial; and the *warm*, flowing in the opposite direction.

In the middle latitudes, where the opposing currents meet, the cold, being heavier, sink beneath the warm, and disappear, continuing their course in the deep waters. These under-currents, having reached the inter-tropical seas, gradually rise again to the surface, where they become heated; and, contributing their waters to the great equatorial current, which flows westward on each side of the equator, they finally return towards the poles.

Hence the general currents of the sea are of three classes: the Polar, the Equatorial, and the Return Currents.

4. Direction. The Polar and Return Currents, were they acted upon by no external force, would move in the line of the meridians, taking the shortest course between the poles and the equator.

Both are, however, deflected from this course by the unceasing action of the Earth's rotation,—the Polar Currents, as they advance, tending more and more towards the west, and the Return Currents towards the east; and their directions are still farther modified by the forms of the basins of the several oceans, and the influence of the prevailing winds in the different zones.

Since the Earth performs one entire rotation on its axis every twenty-four hours, the velocity of rotation at the equator must be somewhat more than 1,000 miles an hour. As each successive parallel has a less circumference than the preceding, the velocity of rotation diminishes with increasing latitude, until at the poles it is null.

If, therefore, particles of water, or of air, move from the polar regions towards the equator, each step in advance will bring them upon parallels where the rotation is more and more rapid. The new velocity cannot be instantaneously acquired; consequently, at each successive parallel, the moving particles are left a little behind, or to the west of their previous position; and when they reach the tropics they are many degrees west of the meridians upon which they left the polar regions.

A similar cause operates to give the Return Currents their eastward tendency. The particles moving towards the poles find, at each successive parallel, a rotary velocity less than at the preceding. Not acquiring the new and less rapid motion instantaneously, they gain a little at each parallel, and find themselves slightly in advance, or to the east of their former position.

This deflection from a direct north and south course, which appears in the atmospheric as well as in the oceanic currents (see page 76, Topic 3), is, therefore, the result of a change of latitude of the moving particles. Were they to remain upon any given parallel, their westward, or eastward, motion would cease; for the solid globe, the waters, and the atmosphere, all rotate together, in obedience to the same laws.

In the northern hemisphere, the Polar and the Return Currents both preserve their normal course, the former flowing towards the southwest, the latter towards the northeast. In the southern hemisphere, the westerly winds which prevail beyond the tropics, and sweep, without interruption, over the broad expanse of the southern sea, turn the Polar Current out of its normal, northwesterly course, directing it towards the northeast. (See map, page 66.)

### II. Currents of the Pacific.

1. The Great Equatorial Current of this ocean occupies the entire breadth of the torrid zone, and consists of two parts, a north and a south current, which are separated by a narrow counter current, moving slowly eastward, in the immediate vicinity of the equator. Both branches begin near the American shores, and advance westward at a nearly uniform rate of two or three miles an hour.

The *South Equatorial Current*, starting from the South American coast, off Punta Parina, moves on uninterruptedly across the eastern half of the ocean; but it is broken up in the western part, where its path is obstructed by innumerable islands. The northern portions are lost among the numerous channels of the Indian Archipelago. The southern portions turn southward, forming the New Zealand and Australian Currents; and finally, meeting the Antarctic Current, they return eastward with it.

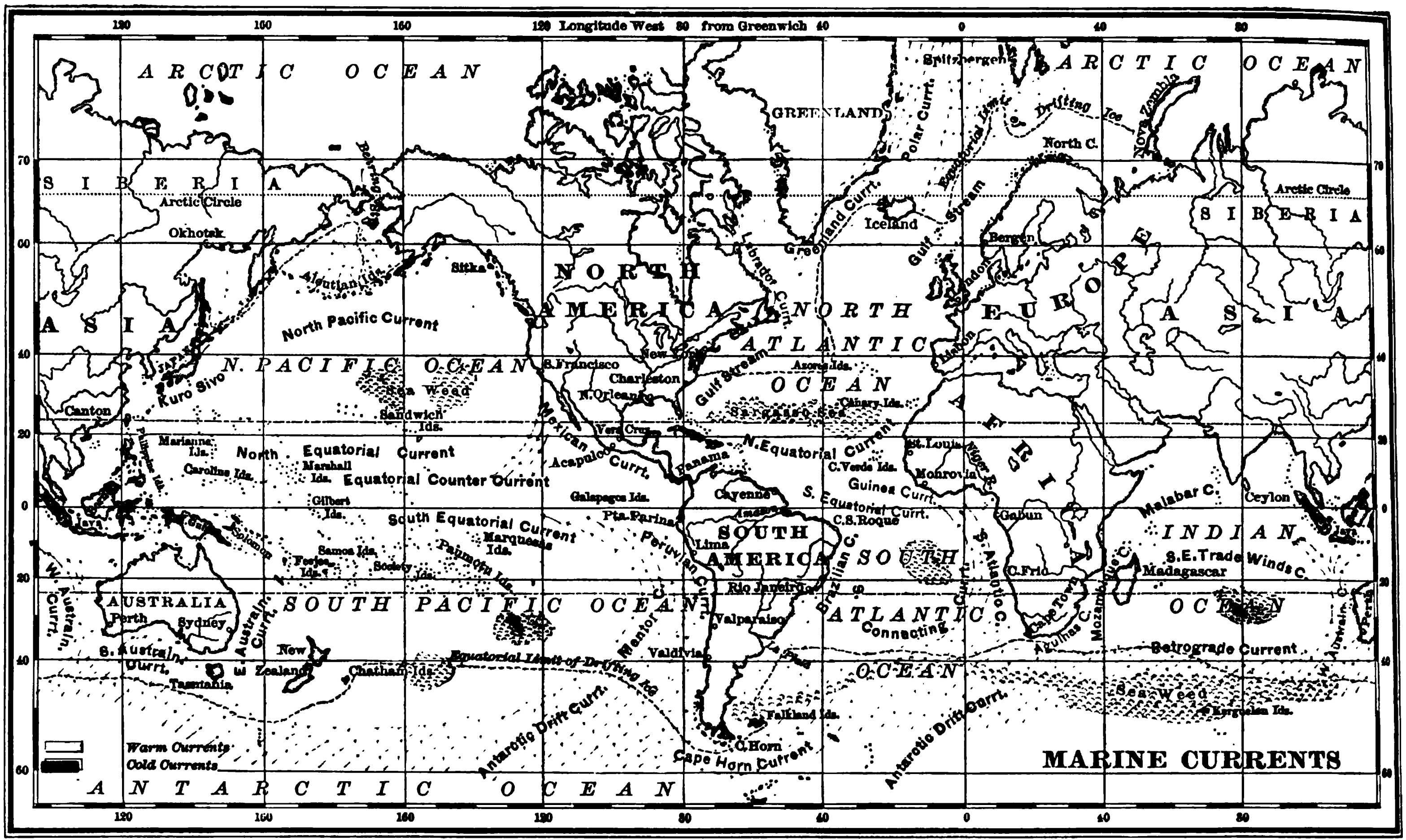
The *North Equatorial Current*, flowing through an unobstructed basin, advances unbroken to the Philippine Islands where it divides, the southern portion entering the Indian Archipelago.

2. Return Current. The principal part of the North Equatorial Current turns northward, forming the warm and powerful Japanese Current, called by the natives the Kuro Sivo, or *Black Water*, on account of its dark-blue color. This is the Return Current of the north Pacific, analogous to the Gulf Stream in the north Atlantic. South of the Aleutian Islands it is deflected from its northward course, and crosses the ocean. Returning along the American shores to the Tropic of Cancer, it chiefly re-enters the North Equatorial Current. A small branch of the Kuro Sivo continues along the Asiatic coast to Behring Strait.

3. Polar Currents are nearly wanting in the north Pacific; for the narrow and shallow passage of Behring Strait, connecting it with the Arctic Ocean, does not permit the free egress of the polar waters. Yet a small current, in each direction, passes through the strait, the warm one on the eastern shore, towards the north, the cold one on the western, towards the south.

In the south Pacific, on the contrary, the polar waters advance northward in the form of the broad Antarctic Drift Current.

# MARINE CURRENTS.



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## QUESTIONS ON THE MARINE CURRENTS.

### I. Pacific Ocean.

Where does the South Equatorial Current commence?
In what longitude does it first divide?
What shores are bathed by the southern branches of this current?
What islands bathed by its northern branches?
What is the position of the counter current in regard to the Equator?
What are the eastern and western limits of this current?
In what longitude does the North Equatorial Current commence?
How does this current compare in breadth with the South Equatorial?
What name has the return current of the North Pacific in the western half of its course?
Where is the Kuro Sivo first apparent?
What shores are bathed by this current?
Near what islands does the Kuro Sivo divide?
Whither does the smaller branch go?
What name is given to the greater branch of the Kuro Sivo?
Describe the course of the North Pacific Current.
What seems to be the most desirable route for vessels from California to China? From China or Japan to California? Why?
What current on the western coasts of South America?
Whence is this current derived?
Whither does it go?
What is the direction of the current east of northern Australia?
What is the direction of the East Australian Current?
Whence are these two currents derived?
What is the direction of the current east of New Zealand, and whither does it go?
Whence come the currents on the west coast of North America?
Whence are all the currents on the west coast of South America derived?
What is their probable effect upon the climate? Why?
Name the principal cold currents of the Pacific.
The warm currents.

### II. Atlantic Ocean.

Trace the water of this ocean, from the Cape of Good Hope to North Cape, naming the currents, and the coasts and islands bathed by each.
Trace, in like manner, the currents from the Cape of Good Hope to Cape St.Roque.
Where is the Gulf Stream first apparent?
Whither does this current go?
What current bathes the southern shores of Iceland?
What current flows between Iceland and Greenland?
What is the position of the North Equatorial Current?
How does the Equatorial Counter Current, in the Atlantic, compare with that in the Pacific in position and extent?
Where does the South Equatorial Current originate?
Whither does the north branch of this current go?
Whither does the south branch mainly go?
Whence are all the currents on the eastern and northern coasts of South America derived?
How does their influence on the climate of the coasts differ from that of the Peruvian Current? Why?
Whence is the current on the western coast of south Africa derived?
Whence are the currents on the western coasts of north Africa and Europe?
What is their probable influence on the climate of those coasts? Why?
Whence are the currents on the larger part of the eastern coast of North America?
How do the currents compare in direction on the opposite sides of the north Atlantic?
What is the direction of the currents at the west of Greenland?
How do the polar currents of the north Atlantic compare in extent with those of the north Pacific?
Why is this?
Name all the warm currents of the Atlantic.
Name the cold currents of the Atlantic.

### III. Indian Ocean.

Trace the course of the currents from the Cape of Good Hope to Australia, and return.
Whence is the South Australian Current derived?
What current flowing between India and Africa?
What is the direction of the currents in the northern part of the Indian Ocean? (See page 67, Topic IV.)
Which are the warm currents of this ocean?
To what part of the Indian Ocean are the cold currents confined? Why?

Bent out of its normal course by the strong westerly winds, this polar current turns eastward, and advances to the South American coast, where it divides. The principal branch flows northward, under the name of the Peruvian or Humboldt Current, bathing the coasts of Peru with its cool waters, and becoming the main feeder of the South Equatorial Current. The smaller branch, turning southward, rounds Cape Horn and enters the Atlantic.

### III. Currents of the Atlantic.

1. The Equatorial Current, in the Atlantic, owing to the narrowness of the basin and the projecting angle of South America, has neither the extent nor the regularity it shows in the Pacific. The northern branch is less marked, and the counter current is not well defined except near the African coasts, where it is known as the Guinea Current.

The south branch advances from the coast of Guinea to Cape St. Roque, the eastern point of South America, where it divides. The smaller division forms the Brazilian Current, flowing southward along the eastern coast of South America. Finally turning to the southeast, under the name of the Connecting Current, it joins the Antarctic waters, and returns with them to the Equatorial Current.

The main portion of the south current continues westward, passing the mouth of the Amazon and the coast of Guiana; then, uniting with the North Equatorial Current, it traverses the Caribbean Sea and the Gulf of Mexico, and issues into the north Atlantic basin as the Gulf Stream.

2. The Gulf Stream, which first becomes apparent near the northeast coast of Cuba, advances gently eastward to the Bahama Banks; then, turning northward, it follows the American coast, with an average velocity of four or five miles an hour, gradually expanding in breadth and diminishing in depth.

In the latitude of New York it turns eastward and crosses to the Azores, where it divides. The main branch, bending southward, enters the tropical regions off the coast of Africa, and returns to the North Equatorial Current. The northern branch continues its northeast course to the British Isles and Norway, its advance in that direction being favored by the prevailing southwest winds.

Near its origin this remarkable current has a breadth of 32 miles, and a depth of more than 2,000 feet; off Cape Hatteras the breadth is at least 75 miles, and the depth about 700 feet. Its temperature, at its origin, is about 80° Fahr.; and through the larger part of its course it is, on an average, from 10° to 15° Fahr., — in winter from 20° to 30°, — warmer than the adjacent waters. Its color is a deep blue, so strongly contrasting with the greenish color of the sea that the line of contact is distinctly traceable by the eye. Its boundaries are sharply defined, especially on the west, where the transition is immediate from the cold wall of adjacent waters to the warm waters of the Gulf Stream.

In the middle and northern part of its course, alternate bands of cold and warm waters occur. This is due, perhaps, to the partial mingling of colder currents with the warm, or simply to the currents of warm water moving into the quiet colder waters of the sea.

The comparatively high temperature and rapid motion, and the deep blue color of the Gulf Stream, distinguish it from other portions of the ocean. It was long supposed to be a phenomenon of an exceptional character, to account for which the most extravagant hypotheses were invented. A better knowledge of the ocean currents, however, shows it to be simply a Return Current like the Japanese, the normal character of which is intensified by the peculiarities of the Atlantic basin.

This basin has scarcely half the breadth of the Pacific basin; hence the Gulf Stream retains, throughout its course, its original temperature in a much higher degree than the Kuro Sivo. Again, the open communication of the Atlantic basin with the Arctic, giving free entrance to the polar waters, while the north Pacific is closed against them, causes a much greater contrast between the Gulf Stream and the surrounding sea than is presented by the Japanese Current.

The intermingling of the warm moist air, over the Gulf Stream, with the colder air over the surrounding sea, causes those frequent and violent storms which mark the course of this current across the Atlantic.

The Gulf Stream transports not only the warm waters of the tropics, but carries with it large quantities of drift wood from the tropical forests. This, with *débris* from wrecked vessels, and weeds from the vast Sargasso Sea, it throws upon the shores and islands of the Arctic regions whither it flows, the drift wood forming a valuable gift to the people of those inhospitable lands.

3. Two main Polar Currents, one on each side of Greenland, uniting off Cape Farewell, carry the icy waters and icebergs of the Arctic to the American shores, as the Gulf Stream and the superincumbent air transport the genial temperature of more southern latitudes to Europe. In the latitude of Newfoundland the Polar Current meets the Gulf Stream, and, condensing the vapors in the warm air which rests upon it, produces almost constant fogs. Thence as far as New York, the polar waters flow between the warmer waters and the shore, finally disappearing beneath them.

### IV. Currents of the Indian Ocean.

The *North Equatorial Current*, in this basin, is overcome by the influence of the Monsoons; and it flows alternately towards and from the southwest, its principal branch being known as the Malabar current.

The *South Equatorial Current* is quite regular, extending from Australia to Madagascar, where it divides. The north branch forms the warm and powerful Mozambique current, west of Madagascar, and near the southern coast of Africa it is joined by the south branch. South of the Cape of Good Hope the united current meets the Antarctic Drift and turns backward with it to the shores of Australia, where it re-enters the equatorial current.

### V. Conclusion.

Thus is kept up, in each of the three great ocean basins, a constant circulation of the marine waters, which far surpasses in magnitude the greatest circulatory systems of the continents, and produces important modifications in the climate of the adjacent lands.

The north polar currents, transporting their icy waters into the middle latitudes, are, by the influence of the Earth's rotation, thrown upon the eastern shores of the continents, reducing their temperature below that belonging to the latitudes.

The return currents, on the contrary, carrying the warm waters, and accompanied by the warm air of the tropical regions, strike the western shores of the continents, and raise their temperature above that belonging to their latitudes. Thus on the opposite shores of the northern continents, there are great contrasts of temperature in the same latitude, due in a considerable degree to marine circulation.

Again, the position of the warm waters on the surface of the sea, while the cold are beneath, doubtless augments, to an appreciable degree, the warmth of the entire temperate zone.

#### ANALYSIS OF SECTION III.

**I. General Currents.**

1. Ocean Currents.
    a. Definition.
    b. Extent.
    c. Position relative to surface.
    d. Cause.
2. Equatorial Currents.
3. Series of Currents.
    a. Cold currents.
    b. Warm currents.
    c. Results of meeting of cold and warm currents.
    d. Under current in equatorial regions.
    e. Classes of general currents.
4. Directions of Polar and Return Currents.
    a. Direction in absence of modifying influence.

- b. Influence modifying directions. Results.
- c. Explanation of direction of polar currents.
- d. Explanation of direction of return currents.
- e. Further modifications of course of currents.

**II. Currents of Pacific Ocean.**

- 1. EQUATORIAL CURRENTS.
  - a. Breadth. Subdivisions. Velocity.
    - South Equatorial current.
    - North Equatorial current.
- 2. RETURN CURRENTS.
  - a. How formed.
  - b. Course.
- 3. POLAR CURRENTS.
  - a. North Polar currents.
  - b. South Polar current. Direction. Course of branches.

**III. Currents of the Atlantic.**

- 1. EQUATORIAL CURRENTS.
  - a. Effect of narrowness and form of basin.
  - b. South branch and subdivisions.
- 2. GULF STREAM.
  - a. Where first apparent.
  - b. Course and velocity at first.
  - c. Subdivisions and their courses.
    - Characteristics of Gulf Stream.
    - Peculiarities how accounted for.
- 3. POLAR CURRENTS.
  - a. Position and character.
  - b. Effect on meeting Gulf Stream.
  - c. Latitude of disappearance.

**IV. Currents of Indian Ocean.**

- a. North Equatorial current.
- b. South Equatorial current.

**V. Conclusion.**

- a. Magnitude of marine circulations.
- b. Climatic effect of Polar currents. Of Return currents.
  - Resulting contrasts in coasts.

## REVIEW OF PART III.

**Introduction.** (Page 47.)

Enumerate the topics discussed in the introductory section.
What is the effect of reducing the temperature of water?
What importance has this exception to a general law of nature?
Whence is the rain water which falls upon the continents, and what becomes of it?

**Continental Waters. I.** (48.)

Explain the formation of intermittent springs.
Where are springs most numerous, and why in this position?
How are rivers combined into systems?
Upon what does the amount of water transported by a stream depend?
How does the erosion vary in different parts of the course of a stream?
(49.) What is the result of the lateral erosion in the middle course?
Explain the sinuosity of the course of streams through the bottom land.
How are the windings changed in high water?
Give examples of the amount of materials transported by streams.
How is this transportation effected, and how do the materials vary in different parts of the course?
How does the deposit of the transported materials vary?
(50.) Describe the formation of deltas.
What peculiarity of slope do deltas show, how is this occasioned, and what is the result of it?
In what of the course of a stream are the highest falls? Why?
Enumerate the topics discussed in Section I., with their primary divisions.

**II.** (51.)

What peculiarities of form distinguish mountain lakes?
What are the characteristics of lakes in plateaus and plains?
How is the formation of salt lakes to be accounted for?
Upon what does their size depend? Examples.
(52.) In what continents are lakes most numerous? Character of the lakes in each?
Enumerate the topics and sub-topics discussed in Section II.

**III.**

What is the influence of the characteristic structure of North America upon its drainage?
What is the main water-shed, and what great streams flow from it?
(53.) Describe the formation of the Mississippi basin.
What is the position of its three principal affluents, and what determines this position?
How do the eastern affluents compare with the western in the amount of water transported?
Why this difference?
What especially characterizes the St. Lawrence basin?
Name the other river systems, and the groups of smaller streams, in North America.
(54.) How do the systems of the central plain compare with the others? Why is this?
Enumerate the topics discussed in Section III.

**IV.**

How does the general plan of drainage in South America compare with that in North America?
What is the effect of the inequality of the continental slopes?
How is the absence of lakes in South America to be explained?
What is the structure of the Amazon basin, and the main source of its waters?
How does the Amazon compare with other streams in its volume of water? Why?
Name the remaining systems of South America, and the corresponding streams of North America.
(55.) Enumerate the topics discussed in Section IV., and their primary divisions.

**V.**

Describe the general plan of drainage in eastern Asia.
Why is it so different from the plan of the American continents?
Enumerate the principal streams on each slope.
Describe the drainage of western Asia.
What are the hydrographical centres of Europe?
Describe the drainage of High Europe.
What governs the direction of the flowing waters of a continent?
(56.) How does the course of the streams of High Europe illustrate this fact?
Describe the drainage of Low Europe.
How do its streams compare with those of High Europe?
Enumerate the topics discussed in Section V., with their several subdivisions.

**VI.** (57.)

What is the general plan of drainage in Africa?
Describe the course of the Nile, its valley, and its inundations.
Describe the other river systems of Africa.
From what part of the continent do these systems derive their waters?
What peculiarity in regard to rivers is exhibited by Australia?
Upon what does the plan of drainage in each continent depend?
What oceans receive the larger part of the flowing waters of the globe?
What is the reason of this?
Enumerate the topics discussed in Section VI., with their subdivisions.

**The Sea. I.** (58.)

What is the composition of sea water?
How does the temperature of the surface vary?
What is the temperature of the deep waters?
Describe the bottom of the sea.
Enumerate the topics discussed in Section I., with their several subdivisions.

**II.** (59.)

Describe the forms of the several ocean basins.
How are coast waters classified, and what class characterizes each ocean?
How do the oceans compare in regard to islands?
Describe the bed of the Atlantic Ocean.
(60.) How does the bed of the oceans differ from the surface of the continents?
Describe the bed of the Indian Ocean.
What is the estimated depth of the Pacific?
How do inland and border seas compare with the oceans in depth? Examples.
What is probably the greatest depth of the sea?
(61.) Enumerate the topics discussed in Section II., with their several divisions.

**III.**

What are the different classes of movement in the waters of the sea?
Describe the wave movement, and the advance of the wave.
Describe the tides, their cause, the extent of the movement, and the several periods of the tides.
How are the tidal waves produced on opposite sides of the globe?
(62.) Explain the spring tides and the neap tides.
Upon what does the velocity of movement of the tidal wave depend?
Describe the tidal wave of the Pacific.
Why is the progress of the wave more rapid in mid-ocean than along the coasts?
(63.) What is the normal height of the tide wave?
Why is it higher along the coasts and in estuaries?
Enumerate the topics discussed in Section III., with their several divisions.

**IV.** (65.)

Describe the general circulation of the oceanic waters.
What are the three classes of ocean currents?
What is the normal direction of the polar, and of the return currents?
How is this direction caused?
How do the polar currents of the southern hemisphere vary from this direction?
Describe the equatorial current of the Pacific.
Describe the course of the Kuro Sivo.
(67.) Describe the equatorial current of the Atlantic.
Describe the Gulf Stream, its course, velocity, and temperature.
How and why does it differ from the Kuro Sivo.
What is the climatic influence of the ocean currents?
What is the effect of the expansion of the warm currents on the surface of the sea, while the cold are beneath?

# PART IV.

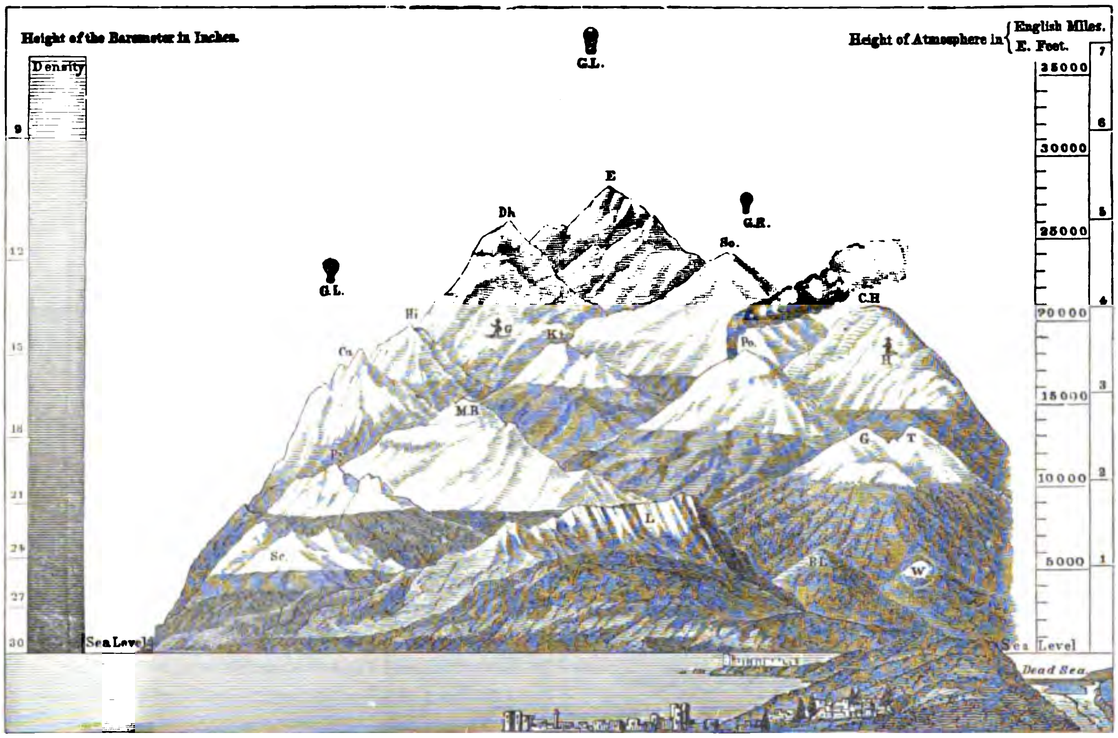
# THE ATMOSPHERE.

## I.—INTRODUCTION.

### I. The Atmosphere a Geographical Element.

1. Its Relation to the other Elements. The Atmosphere, that vast ocean of air at the bottom of which we live, forms the third great geographical element of the Earth. Enveloping both the land and the water, it absorbs the heat and vapors caused by the action of the sun upon the surface of both; and, through the medium of the winds, carries invisible moisture and fertilizing rains from the sea to the parched lands.

2. Composition. The atmosphere is a mechanical mixture of oxygen and nitrogen, in the proportion, by volume, of 21 parts of the former to 79 of the latter; with a very small quantity of carbonic acid, and more or less of watery vapor held in suspension. It is among the most elastic bodies in nature, expanding or contracting with the slightest increase or diminution of temperature, or variation in the pressure which it supports.



Bl. Black Mts. Ca. Caucasus. Ch. Chimborazo. Dh. Dhawalagiri. E. Everest. Gr. Gray's Pk. Hi. Hindoo Koosh. Ki. Kilima Njaro. L. Lebanon Mts. M. B. Mont Blanc. Po. Popocatepetl. Py. Pyrenees. Sa. Sorata. Sc. Scandinavian Mts. T. Torrey's Pk. W. Mt. Washington. *Observers:* G. Gerard. G. L. Gay Lussac. Gl. Glaisher. Gn. Green. H. Humboldt.

FIG. 31. DENSITY AND PRESSURE OF THE AIR AT DIFFERENT ALTITUDES.

3. Weight and Pressure. The weight of the atmosphere is measured by its pressure on the barometer.[1] This instrument is a slender glass tube about a yard in length, closed at one end, then filled with mercury and reversed, the open end being placed in a cup of the same fluid.

The atmosphere, pressing upon the fluid in the cup, keeps within the tube a column of mercury exactly sufficient to balance its own weight. At the level of the sea this column, measured by a scale attached to the instrument, is about thirty inches in height. The weight of the entire atmosphere, therefore, is equivalent to that of a layer of mercury thirty inches deep, covering the globe, and exerting a pressure of fifteen pounds on every square inch of its surface.

When, from any cause, the pressure of the air increases, the barometer rises; when it decreases, the barometer falls.

4. Density. The air, being a highly elastic body, the lower layers, which support the pressure of the entire atmosphere, are the most dense; and the density diminishes upward with the decrease of pressure and the consequent increase of volume.

The law of variation is exhibited in the table below, in which the volume and density of a given weight of air at the sea level, under a barometric pressure of thirty inches, is taken as unity.

| Height of Barometer. Inches. | Volume of a given weight. | Density. | Miles above sea level. |
|---|---|---|---|
| 30.00 | 1 | 1 | 0 |
| 15.00 | 2 | $\frac{1}{2}$ | 3.4 |
| 7.50 | 4 | $\frac{1}{4}$ | 6.8 |
| 3.75 | 8 | $\frac{1}{8}$ | 10.2 |
| 1.87 | 16 | $\frac{1}{16}$ | 13.6 |
| .93 | 32 | $\frac{1}{32}$ | 17.0 |

It will be seen that one half of the entire atmosphere, by weight, is condensed within $3\frac{2}{5}$ miles—about 18,000 feet—of the sea level; and fully two-thirds are below the level of the summit of the highest mountains. This fact has an important bearing, both on the influence of mountains in directing or modifying the course of the winds, and on the general climatic phenomena of the globe.

Fig. 31 shows the diminution of barometric pressure, with increasing altitude, up to the highest points reached by observers, either upon mountains or by balloon, the highest being *Glaisher's* balloon ascent to 36,670 feet.

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[1] From the Greek *baros*, weight, and *metron*, measure.

5. Height of the Atmosphere. In consequence of the above law of diminution, it is calculated that, at the height of from 45 to 50 miles above the sea, the atmosphere becomes so rarefied that the barometric pressure is nearly or quite insensible. If this be taken as practically its upper limit, the atmosphere appears as a thin film, measuring not much more than the hundredth part of the radius of the Earth.

6. Its Relation to Organic Life. In the atmosphere alone the highest forms of vegetable and animal life, including man himself, find the proportion of heat, of oxygen, and of watery vapor requisite for their vitality and development. It thus performs the part of universal mediator, not only between land and sea, but also between organic and inorganic nature.

## II. Climate.

1. Definition. The physical agencies acting through the atmosphere upon organic life, constitute *climate*, of which heat and moisture are the essential elements, the winds being the medium of circulation. Of these, *temperature*, however, is the fundamental phenomenon of climate; for the winds and the rains result from differences in the temperature of the air.

2. Astronomical Climate. The fundamental laws which govern the climatic conditions of our globe are the result of astronomical causes; namely, the direct action of the Sun's rays upon the Earth's surface, the spherical form of the Earth, and the daily and yearly motions of the latter. These causes, operating constantly, establish permanent inequalities of temperature and rainfall in different latitudes; and periodical variations, in the same latitude, in different parts of the year.

The general climatic conditions belonging to a region, and depending upon its latitude, constitute its *astronomical climate.*

3. Physical Climate. The climate belonging to a place, by its latitude, is usually modified, to a greater or less extent, by secondary physical agencies, — among which are the general atmospheric and marine currents, the differing power of land and water to absorb and radiate heat, and the altitude of the surface.

The astronomical climate of a region thus modified, is its real, or *physical climate.* This depends not only upon its latitude, but also on its position in regard to the oceans, the direction of its prevailing winds, and its elevation above the level of the sea.

### ANALYSIS OF SECTION I.

**I. The Atmosphere a Geographical Element.**

1. Its Relation to other Elements.
2. Its Composition and Elasticity.
3. Its Weight and Pressure.
4. Its Density.
5. Its Height.
6. Its Relation to Organic Life.

**II. Climate.**

1. Definition.
    - a. Essential elements.
    - b. Fundamental phenomenon.
2. Astronomical Climate.
    - a. General climatic conditions — how caused.
    - b. Results of operation of astronomical causes.
    - c. Astronomical climate defined.
    - d. Astronomical climate depends on what.
3. Physical Climate.
    - a. Subordinate agencies modifying climate.
    - b. Physical climate defined.
    - c. Physical climate depends on what.

## II. — ASTRONOMICAL CLIMATE.

## I. Distribution of Temperature.

1. General Law. The amount of heat produced by the sun upon the Earth's surface, is greatest near the Equator, and diminishes gradually towards the Poles.

2. Causes of Variation. Three general causes, each referable to the spherical form of the Earth, combine to produce the gradual diminution of temperature from the Equator to the Poles.

(1.) The *angle* at which the Sun's rays impinge upon the surface. In the Equatorial regions they are perpendicular to the surface of the sphere, and there produce their maximum effect; but, on account of the curved outline of the globe, they fall more and more obliquely with increasing latitude, and the intensity of action diminishes proportionately. At the Poles, they are tangent to the surface, and their effect is null.

(2.) The *area* on which a given amount of heating power is expended, is least at the Equator, consequently the resulting heat is greatest. The area covered increases, and the effect diminishes, with the increasing obliquity of the Sun's rays in higher latitudes, which, as we have seen above, results from the spherical form of the Earth.

(3.) The *absorption of heat* by the atmosphere, as the Sun's rays pass through it, is least where they fall perpendicularly, — that is, in the Equatorial regions, — and increases, with their increasing obliquity, towards the Poles.

## II. Influence of the Earth's Motions.

1. Motions of the Earth. The Earth revolves constantly around the Sun, and at the same time rotates upon an axis inclined 23½° towards the plane of its orbit. In consequence of the inclination of the axis, the declination of the Sun, or its angular distance from the Equator, varies with the advance of the Earth in its orbit, causing periodical variations in the length of day and night, and, consequently, in temperature.

2. Positions of the Vertical Sun. *Vernal Equinox.* On the 20th of March, at mid-day, the Sun is vertical at the Equator. Rising directly in the east it ascends the heavens to the zenith, and, descending, sets directly in the west.

The illuminated hemisphere extends from pole to pole, and embraces half of every parallel of latitude; hence every point on the Earth's surface is under the rays of the Sun during half of the diurnal rotation; the days and nights are equal all over the globe; and the heating power of the Sun is the same in both the northern and the southern hemisphere. (See illustration Orbit of the Earth, page 5.)

*Summer Solstice.* As the Earth advances in its orbit the vertical Sun declines northward; and on the 21st of June, at the Summer Solstice, it is over the northern Tropic, 23½° from the Equator.

The illuminated hemisphere, extending 90° on each side of the parallel of the vertical Sun, reaches 23½° beyond the north pole; but, at the south, it barely touches the Antarctic circle. It embraces more than half of each parallel north of the Equator, hence throughout the northern hemisphere the day is longer than the night, the difference in their duration increasing with the latitude; and all points within the Arctic circle are in the light during the entire rotation.

In the southern hemisphere, less than half of each parallel being illuminated, the night is longer than the day, and within the Antarctic circle there is constant night. The heating power of the Sun is now at the maximum in the northern hemisphere, while in the southern it is at the minimum.

At the *Autumnal Equinox*, on the 22d of September, the distribution of light and heat upon the two hemispheres is the same as at the Vernal, and at the *Winter Solstice*, on the 22d of December, it is the reverse of that at the Summer Solstice.

3. VARIATIONS IN TEMPERATURE. The *inequality in the length of the days* in different parts of the year, occasioned by the inclination of the Earth's axis, is of itself sufficient to produce a marked variation in temperature.

During the day the Earth receives from the Sun more heat than it radiates into space; while during the night it radiates more than it receives. Hence a succession of long days and short nights results in an accumulation of heat, raising the average temperature and producing summer; while long nights and short days result in a temperature below the average, producing winter.

Again, the *heating power of the Sun* in each hemisphere is greatest at the period of the longest days, because of its greater altitude in the heavens; and least at the period of shortest days. Thus long days and a high sun operate together to produce the high temperature of summer; while long nights and a low sun cause the low temperature of winter.

4. VARYING INEQUALITY OF DAY AND NIGHT. *Law of variation.* The inequality of day and night increases slowly in the tropical regions, but more and more rapidly towards the polar circles. Beyond these circles the Sun, in the hemisphere in which it is vertical, makes the entire circuit of the heavens, without sinking below the horizon, for a period varying from twenty-four hours to six months; while in the opposite hemisphere there is a corresponding period of continuous night.

The following TABLE gives the length of the longest day, excluding the time of twilight, and of the shortest night, in the different latitudes, with the difference of duration in hours and minutes, thus exhibiting more clearly the above law.

| LATITUDE. | Longest Day. | Shortest Night. | Difference. | LATITUDE. | Longest Day. | Shortest Night. | Difference. |
|---|---|---|---|---|---|---|---|
| Equator . . | 12.0 hours. | 12.0 hours. | 00.0 hours. | 55° . . . | 17.3 hours. | 6.7 hours. | 10.6 hours. |
| 10° . . . | 12.7 " | 11.3 " | 1.4 " | 60° . . . | 18.7 " | 5.3 " | 13.4 " |
| 20° . . . | 13.3 " | 10.7 " | 2.6 " | Polar Circles | 24.0 " | 0.0 " | 24.0 " |
| Tropics . . | 13.5 " | 10.5 " | 3.0 " | 67½° . . . | 1 month. | 0.0 " | - |
| 30° . . . | 14.0 " | 10.0 " | 4.0 " | 69½° . . . | 2 months. | 0.0 " | - |
| 35° . . . | 14.5 " | 9.5 " | 5.0 " | 73.3° . . | 3 " | 0.0 " | - |
| 40° . . . | 15.0 " | 9.0 " | 6.0 " | 78.3° . . | 4 " | 0.0 " | - |
| 45° . . . | 15.6 " | 8.4 " | 7.2 " | 84° . . . | 5 " | 0.0 " | - |
| 50° . . . | 16.3 " | 7.7 " | 8.6 " | North Pole . | 6 " | 0.0 " | - |

*Result of Varying Inequality.* In the tropical regions, where the days and nights vary little in length, the temperature is nearly uniform throughout the year; while the increasing inequality of day and night towards the Poles, causes an increasing difference between the summer and the winter temperature.

Again, the length of the day, in the summer of high latitudes, compensates for the diminished intensity of the Sun's influence; so that the temperature, in the hottest part of the day, may equal, or even exceed, that within the tropics. A summer day in Labrador or St. Petersburg may be as warm as one under the Equator; but in the former latitudes there are only a few days of extreme heat in the year, while with increasing nearness to the Equator the number of warm days constantly increases.

5. SEASONS IN DIFFERENT LATITUDES. The *high latitudes* have short, hot summers, and long, severe winters. The transition seasons, spring and autumn, on account of the very rapid change in the length of the days, are short and scarcely perceptible.

In the *middle latitudes* the summer and winter are more nearly equal in length, with less difference in the extreme temperatures; and the transition seasons are distinctly marked. Farther towards the Equator the summer increases in length, and the winter diminishes, while the *tropical latitudes* have constant summer.

Though in middle and polar latitudes, the intensity of the Sun's rays is greatest at the time of the Summer Solstice, yet the highest degree of heat, resulting from accumulation during the long days, does not occur until a month or more after that period. The lowest temperature, consequent upon successive losses during the short days, usually occurs a month or more after the Winter Solstice.

A similar fact is apparent in the daily alternations of temperature. The highest degree of heat is not at noon, when the sun is highest, but about two o'clock; and the lowest, a little before sunrise, at the end of the period of greatest radiation, instead of at midnight.

### ANALYSIS OF SECTION II.

**I. Distribution of Heat on Globe.**
- a. General law.
- b. Causes of unequal distribution.
- c. Operation of each.

**II. Effects of Earth's Motions.**
- 1. MOTIONS OF THE EARTH.
  - a. Result of inclination of axis.
- 2. POSITIONS OF VERTICAL SUN.
  - a. Vernal equinox.
    - When occurring. Daily course of Sun.
    - Position of illuminated hemisphere.
    - Length of day and night.
    - Comparative heat of hemispheres.
  - b. Summer solstice.
    - When occurring.
    - Position of illuminated hemisphere.
    - Day and night in northern hemisphere.
    - Day and night in southern hemisphere.
    - Comparative heating of hemispheres.
  - c. Autumnal equinox and winter solstice.
- 3. VARIATIONS OF TEMPERATURE.
  - a. Variation in length of day.
    - Effect of long days and short nights.
    - Effect of long nights and short days.
  - b. Variation in heating power of sun.
- 4. VARYING INEQUALITY OF DAY AND NIGHT.
  - a. Law of variation.
  - b. Result of variation.
    - Summer day of high latitudes.
- 5. SEASONS.
  - a. In high latitudes.
  - b. In middle latitudes.
  - c. In tropical latitudes.
  - d. Time of highest and of lowest temperature.
  - e. Daily alternations of temperature.

## III. — PHYSICAL CLIMATE.

### I. Contrasts in the same Latitude.

1. CONTRASTS OBSERVED. According to the laws of astronomical climate, all places having the same latitude would have the same average annual temperature, and the same periodical changes. Thermometric observations, however, show quite a different state of things. In many cases the differences in average annual temperature, in regions having the same latitude, and the resulting contrasts in the aspects of nature, are extreme; while the differences in the character of the seasons are no less strongly marked.

For example, — on the western shore of the Atlantic Ocean is Labrador, frozen and treeless; while opposite, in the same latitude, are the British Isles, with their mild climate, fertile soil, and rich verdure. New York, with a long icy winter, is in the same latitude with Naples, surrounded by orange groves and evergreen vegetation. Again, San Francisco, with mild winters and cold summers, is on the same parallel with Washington, where a burning sun in summer is succeeded by winters so cold as often to cover the Potomac with a thick coat of ice; and the fruitful plains of southern China lie side by side with the frozen, and almost uninhabitable, wastes of Thibet.

2. ISOTHERMAL LINES. In order to illustrate the actual distribution of heat, irrespective of latitude, Humboldt devised a series of lines known as *isothermals*,[1] or lines of equal average temperature, as ascertained by thermometric observations. Each line connects places having the same mean temperature, either of the year, a season, or any one month. The *annual isothermals* show the average temperature belonging to the places which they connect; the *monthly* and *season isothermals* show the distribution of heat throughout the year.

A correct delineation of the isothermal lines of the globe will, therefore, show most clearly the general deviations from the astronomical climates in all parts of the Earth. Where the isothermals bend from the parallels in the direction of the Poles, they indicate an average temperature higher than belongs to the latitude; where they approach the Equator, they indicate a temperature lower than belongs to the latitude.

## II. Deviations from Astronomical Climates.

1. The GENERAL DEVIATIONS from the astronomical climate occur chiefly in the middle latitudes, and may be distinguished as primary and secondary. The first are deviations from the *mean annual temperature* belonging to a given latitude, caused mainly by the influence of the general winds and the marine currents. The second are departures from the average *summer* and *winter temperatures* belonging to a given latitude, occasioned chiefly by differences in the absorbing and radiating power of land and water.

2. LOCAL DEVIATIONS, the result of elevation, occur in all latitudes. They consist in a reduction, proportionate to the altitude, of the mean temperature belonging to the latitude; while the periodical changes remain very nearly the same. On an average, an increase of 330 feet in altitude diminishes the temperature 1° Fahr.; hence the rate of diminution is about 3° to 1,000 feet.

In tracing the isothermals, according to Humboldt's example, the local influence of altitude is usually eliminated. This is done, as in the accompanying map, by adding, to the observed temperature of a place, 1° for every 333 feet of its elevation, thus reducing the temperature to that which the place would have if situated at the level of the sea.

In large plateaus, however, the effect of altitude seems to be, in some measure, counteracted by the great extent of absorbing and radiating surface uplifted into the atmosphere. In general they are considerably warmer than the isolated summits of mountains of the same altitude.

## III. Influence of Winds and Marine Currents.

1. MODE OF OPERATION. *Winds* from the equatorial regions carry into the middle latitudes some portion of the heat of the tropical regions; while polar winds bring the low temperature of the latitudes whence they come. If, therefore, either the polar or the equatorial wind prevails throughout the year in a particular region, a large amount of heat is added to, or subtracted from, that which belongs to the latitude.

*Marine currents* produce a similar effect, and combine with the winds to cause the primary modifications of the astronomical climates.

2. THE OBSERVATION OF THE ISOTHERMALS traced upon the map, brings to light several important facts in regard to the distribution of temperature on the globe.

(1) The *greatest modifications* of the astronomical climates occur in the northern hemisphere, the isothermals of the southern hemisphere departing far less from the parallels of latitude.

(2) The *extreme deviations* occur on the coasts of the north Atlantic, western Europe being very much warmer than eastern America in corresponding latitudes. The difference in the temperature of the opposite coasts increases towards the pole.

The isothermal of 50° Fahr., which passes near New York, on the 40th parallel of latitude, reaches London, on the opposite side of the Atlantic, eleven degrees farther north. The isothermal of 40° Fahr. passes through Canada and Nova Scotia, near the 46th parallel, but lies eighteen degrees farther north on the European coast. The isothermal of 30° Fahr. connects central Labrador with North Cape in Europe, the two places differing in latitude by twenty-one degrees.

Similar deviations take place in the north Pacific, but the differences of temperature on the opposite coasts are only about one-half as great as on the Atlantic coasts.

In the *northern hemisphere*, the winds and marine currents from the equatorial regions, are directed towards the northeast, thus raising the temperature of the western coasts of the continents; while the polar winds and currents strike the eastern coasts, lowering their temperature.

The return-trades of the Atlantic (see page 79, Topic II., 4), moving northeastward over the warm surface of the Gulf Stream, absorb a portion of its

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[1] From the Greek *isos*, equal, and *therme*, heat.

## QUESTIONS ON THE MAP OF TEMPERATURE.

Explain the coloring of the map. (See margins, pages 74, 75.) Explain the lines of red and blue.

Explain the figures near the isothermal lines, and those accompanying the names of places.

Where are the regions of greatest heat? What is the average temperature of these regions?

Near what cities in Asia, Africa, and North America does the isothermal of 70° pass?

Where does this line have its nearest approach to the equator?

What is indicated by this position of the line? (See text above.)

How do you account for the comparatively low temperature of the eastern coast of Asia? (See Topic III., 1, below, and *Map of Winds*, pages 80, 81.)

Where is the northern isothermal of 70° farthest from the equator?

What places in Australia, Africa, and South America on the southern isothermal of 70°?

Where does this line approach nearest to the equator?

How do you account for the comparatively low temperature on the Pacific shores of South America? (See *Map of Marine Currents*, page 66.)

Where does the southern isothermal of 70° depart farthest from the equator?

How is this departure to be explained? (See page 67, IV.)

Trace the northern isothermal of 30° across Asia, Europe, and North America.

How does its position in the interior of Asia, Europe, and North America compare with its position on the Atlantic and Pacific coasts?

How do you explain this approach to the equator? (See Topic III., 1, above, and *Map of Winds*.)

How does the position of the isothermal of 30° compare on opposite sides of the Atlantic?

Explain this northward deviation on the eastern coast. (See Topic III., (2), above.)

How does the deviation of the isothermals between 70° and 30° vary from south to north?

What important places in Asia, Europe, and North America lie on or near the isothermal of 60°? Of 50°? Of 40°?

Where are the regions of greatest cold found?

What isothermal forms the southern boundary of these regions?

In which continent is this frigid region most extensive?

How do the isothermals of the southern hemisphere compare with the northern, in the amount of their deviation from the parallels?

Near what parallel is the equatorial limit of drifting ice in the southern hemisphere?

Where does the Antarctic ice advance nearest to the equator?

Where, in the open seas, is the southern ice limit farthest from the equator?

How far southward does the Arctic ice drift on the western shores of the Atlantic?

How far on the eastern shores?

How do the temperatures of the ocean compare with those of the continents in summer? (See small map of summer isothermals.)

Why is this? (See page 73, Topic IV., 1.)

How do the oceanic and continental temperatures compare in winter? Why?

Where and what is the highest average summer temperature of the New World? Of the Old World?

How do these averages compare?

Why is the summer of northern Africa and Arabia so much warmer than the corresponding regions of the New World? (See page 73, Topic IV., 2.)

heat, which they spread, with their own, over western Europe; but the return-trades of the Pacific derive little or no additional heat from the Japanese current, which, owing to the breadth of the basin it has to traverse (see page 65, Topic II., 2), becomes cool before reaching the American shores.

Thus the western coast of North America has its temperature augmented by the equatorial winds alone, while western Europe has the heating influence of the winds and the Gulf Stream combined; hence the higher temperature of the latter.

In the *southern hemisphere*, branches of the equatorial current sweep along the eastern coasts, while the polar currents strike the western; the former, therefore, are warmer, and the latter cooler, than the latitude would indicate.

(3.) In both of the great land-masses of the *northern hemisphere* — Asia-Europe and North America — the western coasts are warmer than the eastern, while in the *southern hemisphere*, where the influence of the marine currents from the Antarctic predominates, the eastern coasts are the warmer.

(4.) *Zones of physical climate* are bounded by the isothermals, while the astronomical zones are limited by the tropics and the polar circles. The true *torrid zone* may be regarded as terminating, on each side of the equator, at the isothermal of 70° Fahr., beyond which the characteristic plants and animals of tropical regions disappear. The temperate zones lie between the isothermals of 70° and 30° Fahr.; and the frigid, extend from the latter to the poles.

Thus defined, the torrid zone is broadest in Africa, the temperate in Europe, the frigid in Asia. Hence it appears that, on an average, Africa, the largest land mass within the tropics, is the hottest of the continents; Europe, the smallest of the northern continents, is the warmest in the temperate zone, while Asia, the largest of all, is the coldest. The two Americas, both in regard to size and temperature, occupy an intermediate grade.

On the whole, therefore, we may conclude that, in the torrid zone, the greater the extent of the land the higher is its temperature, while in the temperate zone the reverse is true.

## IV. Influence of Continents and Oceans.

1. ABSORPTION AND RADIATION. *Water* has a great capacity for absorbing heat, and but feeble conducting power; hence the sea grows warm slowly under the rays of the sun and never attains a high temperature. It also radiates heat slowly, and as fast as the surface particles become cool, they sink and are replaced by warmer ones from beneath; hence the cooling process is as gradual as the heating, and neither produces extremes of temperature.

The *land* absorbs the solar heat rapidly, and the surface soon attains a high temperature. Especially is this the case where the soil is imperfectly covered with vegetation, as in treeless plains or deserts. But when the sun is withdrawn, heat radiates with rapidity, and a comparatively low temperature is soon reached.

2. RESULT. This inequality in the capacity of land and water for absorbing and radiating heat, gives rise to the secondary modifications of the astronomical climates, affecting more especially the amount of heat in the various seasons. In summer, the land is warmer than the sea in the same latitude; in winter, colder. Along the coasts the mingling of the air from the ocean with that over the land, moderates both the heat of summer and the cold of winter; hence the coasts have more equable season temperatures than the interior. The position of the isothermal lines for the various seasons is also modified by this cause.

The following *table* exhibits the rapid increase in the difference between the summer and the winter temperature, as the equalizing influence of the sea is lost by distance. It gives the *average temperature* of the coldest, and of the warmest month of the year, in places situated in the same latitudes but at different distances from the sea.

| NAMES OF PLACES. | Lat. | Jan. Fahr. | July. Fahr. | Diff. | NAMES OF PLACES. | Lat. | Jan. Fahr. | July. Fahr. | Diff. |
|---|---|---|---|---|---|---|---|---|---|
| Faröe Islands . . | 62° | 39.0 | 61.7 | 22.7 | Eastport, Maine . | 45° | 22.5 | 62.4 | 39.9 |
| Bergen, Norway . | 60° | 94.9 | 60.3 | 25.4 | Ft. Snelling, Minn., | 45° | 13.1 | 73.4 | 60.3 |
| St. Petersburg, Rus. | 60° | 15.6 | 62.6 | 47.0 | Bermuda, Atlantic, | 32° | 62.2 | 84.2 | 21.6 |
| Yakutsk, Siberia . | 62° | -43.8 | 62.2 | 106.0 | Natchez, Miss. . . | 32° | 52.2 | 81.3 | 29.1 |
| Penzance, England, | 50° | 42.6 | 62.0 | 19.4 | Madeira, Africa. . | 32° | 63.5 | 73.8 | 10.3 |
| Barnaul, Siberia . | 53° | -4.7 | 67.1 | 71.8 | Cairo, Egypt . . . | 30° | 56.3 | 86.6 | 30.3 |

The *extreme temperatures* in summer and winter differ to a still greater degree. The highest temperature ever observed at the Faröe islands is only 65.3° Fahr., and the lowest is rarely below the freezing point. In St. Petersburg, 2° farther south, extremes of 92°, and —40° Fahr. have been recorded. Nearer the tropics, though the difference between the seasons is less, the influence of the continents and the oceans is still apparent. The extremes of temperature in Madeira show a difference of only 20° to 27°, while in Egypt the difference is 56° Fahr.

3. CONTINENTAL AND OCEANIC CLIMATES. In general the *climate of the oceans* is characterized by uniformity, the difference between the summer and the winter temperature being comparatively slight. The *continental climate*, on the contrary, is characterized by sudden changes, and extremes, the difference between the summer and the winter temperature, in middle and high latitudes, being excessive.

This *difference in land and sea climates* is sufficient to modify the average temperature of the entire globe. In consequence of the great preponderance of land in the middle latitudes of the northern hemisphere, and of water in the southern, the former has a hot summer, and the latter, at the same period, a mild winter. The two combined give, according to Prof. Dove, an average temperature of 62.4° Fahr. for the entire globe, in July, or during the northern summer. In like manner the winter of the northern hemisphere is colder because of the preponderance of land; while the summer of the southern is less warm because of the excess of water. Hence in January, or during the southern summer, the average temperature of the earth is but 54.3° Fahr.; that is, 8.1° lower than in July.

### ANALYSIS OF SECTION III.

**I. Contrasts in the Same Latitude.**

- 1. CONTRASTS OBSERVED.
    - a. General statement.
    - b. Examples.
- 2. ISOTHERMAL LINES.
    - a. Definition and use.
    - b. Annual isothermals.
    - c. Monthly and season isothermals.

**II. Deviations from Astronomical Climates.**

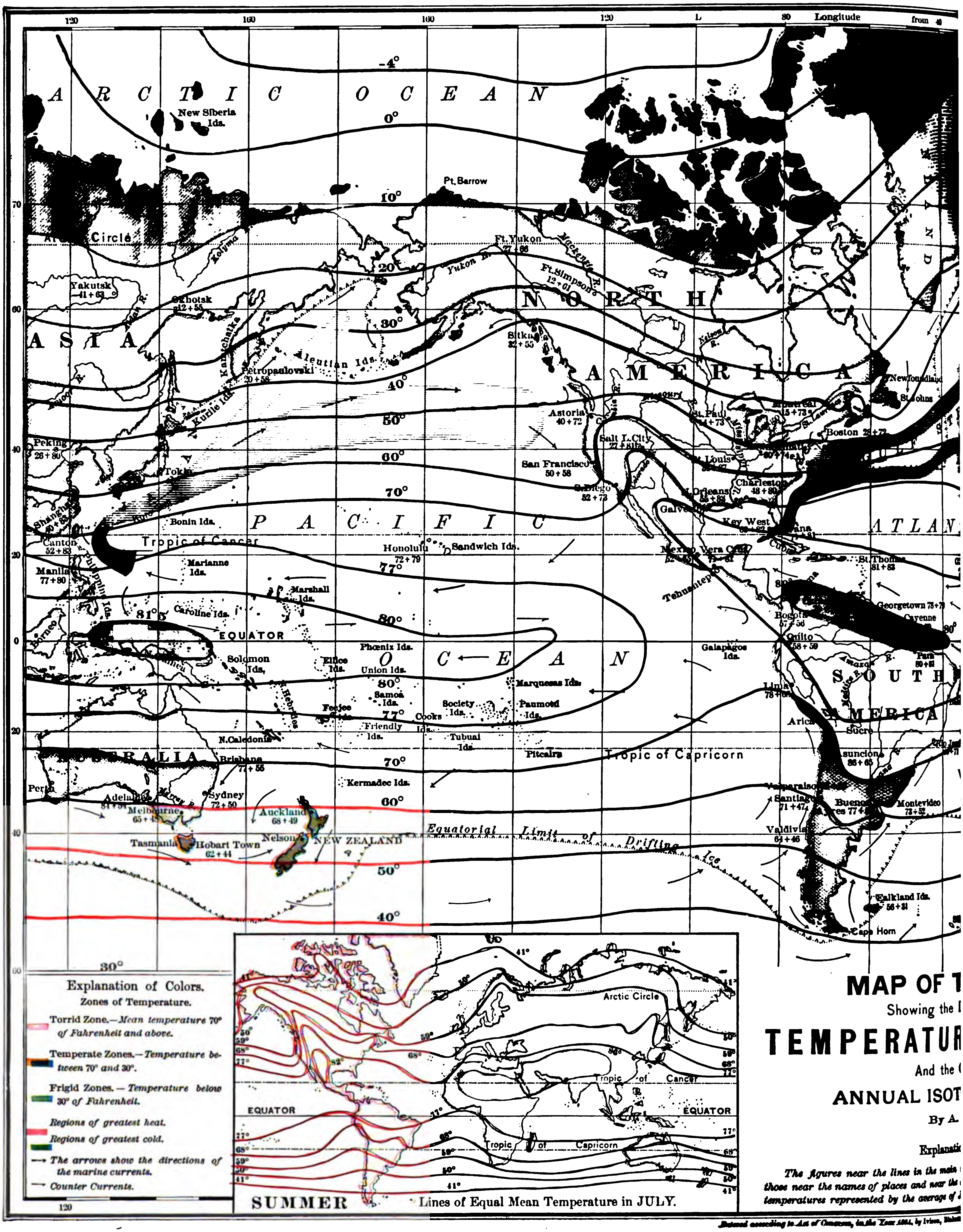
- 1. GENERAL DEVIATIONS.
    - a. Where occurring.
    - b. How classed.
    - c. Character and cause.
- 2. LOCAL DEVIATIONS.
    - a. How occasioned.
    - b. Where occurring.
    - c. In what consisting.
    - d. Rate of diminution.
    - e. How treated in tracing isothermals.
    - f. Temperature of plateaus.

**III. Influence of Winds and Marine Currents.**

- 1. MODE OF OPERATION.
    - a. Winds.
        - Equatorial.
        - Polar.
        - Result of predominance of either.
    - b. Marine currents.
- 2. EFFECTS.
    - a. Greatest modifications where.
    - b. Extreme deviation where. Examples.
        - Deviations on Pacific coast.
        - Explanation.
            - Heating influences in Atlantic.
            - Heating influences in Pacific.
            - Conditions in southern hemisphere.
    - c. Coasts of land masses.
    - d. Average temperature of oceans.
    - e. Zones of physical climate.
        - Limits. Extent in the several continents.
        - Temperature of the continents compared.
        - Effect of greater area of land.

**IV. Influence of Land and Water Surface.**

- 1. ABSORPTION AND RADIATION OF HEAT.
    - a. Water, how affected.
    - b. Land, how affected.
- 2. RESULTS.
    - a. General character of seasons of continents.
    - b. Modifying influence on coasts.
    - c. Table.
    - d. Comparison of extremes of temperature.
- 3. CONTINENTAL AND OCEANIC CLIMATES.
    - a. Characteristic of oceanic climates.
    - b. Characteristic of continental climates.
    - c. Effects on average temperature of globe.



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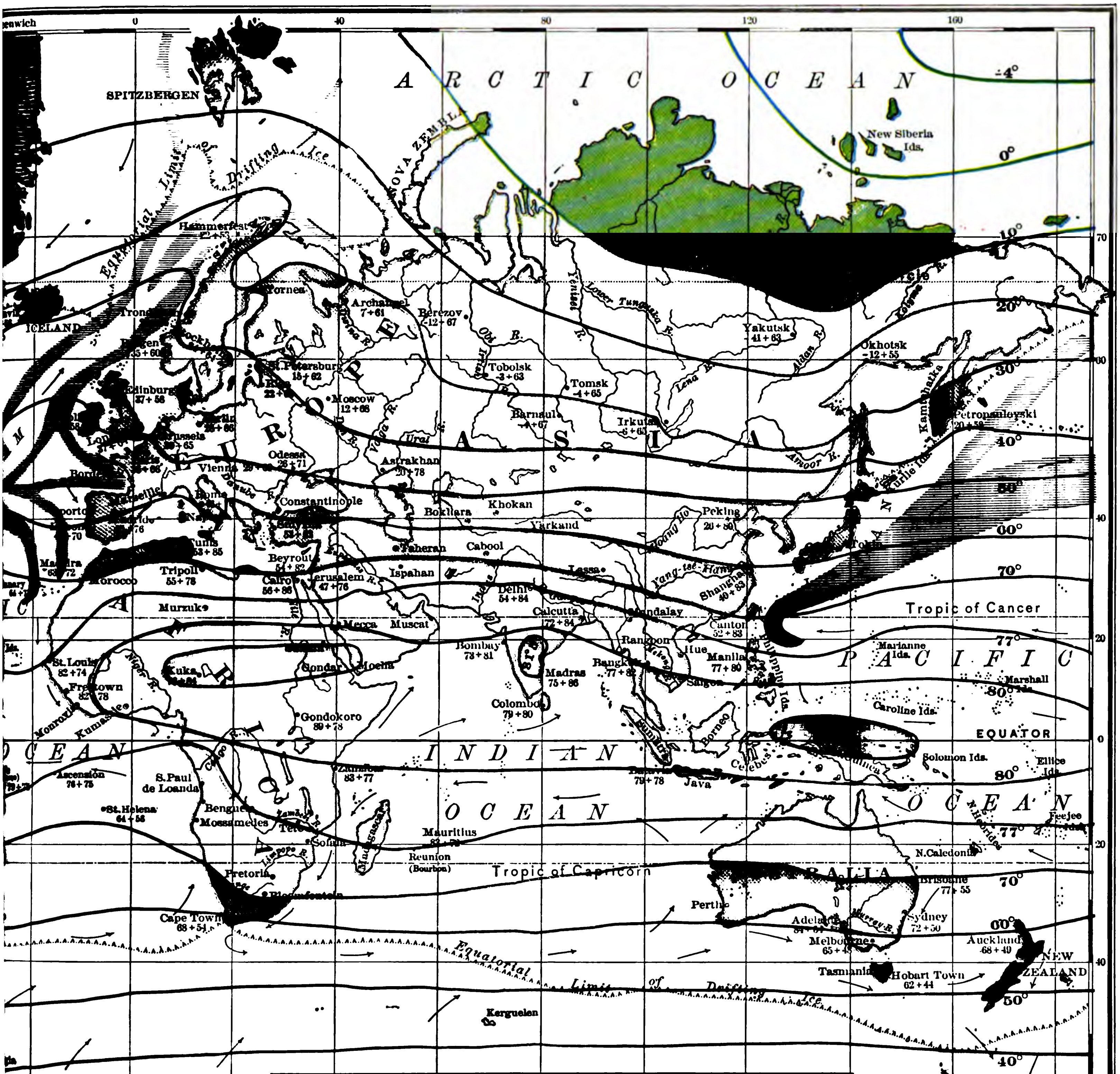

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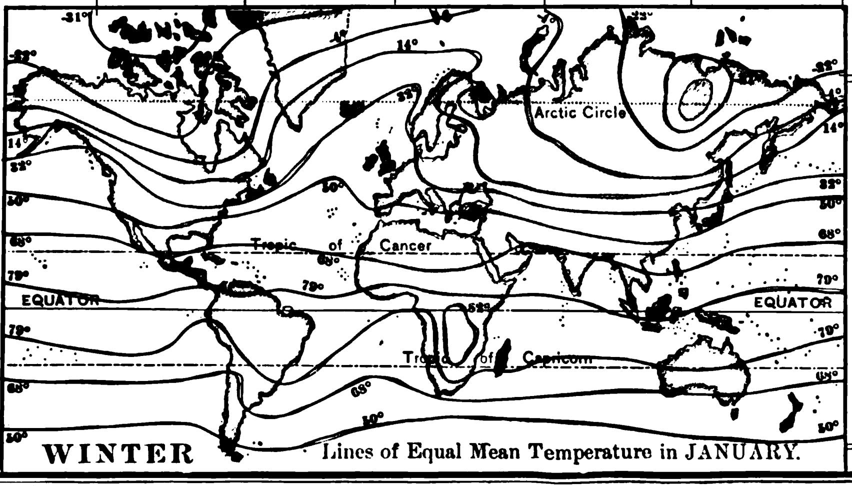

**WINTER** Lines of Equal Mean Temperature in JANUARY.

### Explanation of Lines.

*The lines in the main map pass through places having the same average annual temperature and are called Isothermal lines, meaning lines of equal mean heat. The temperatures are corrected for the effect of the elevation above the sea level. Their curving towards the poles denotes a greater, and towards the equator, a lesser degree of heat than that due to the latitude.*

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## IV. — THE WINDS.

### I. Equilibrium of the Atmosphere.

1. Conditions of Equilibrium. The atmosphere, under the influence of gravity, tends always so to adjust itself as to be in a state of equilibrium, the chief condition of which is a uniform density at any given altitude, the density diminishing upward with the decreasing pressure (see page 69, Topic IV.). But the continuance of this equilibrium requires uniformity of temperature, as well as of pressure, in all parts of the same stratum of air.

2. Disturbance. If any given stratum, whether in the lower or the upper air, is unequally heated in different parts, the equilibrium is destroyed. The warmer portion expands and becomes lighter; and, being pressed upon by the adjacent colder and heavier air, it rises, and its place is occupied by the latter.

This process results in an ascending current, from the region of greatest heat, and horizontal currents flowing from all directions towards that region.

**This is exemplified in a heated stove, where the warm, light air, ascending through the pipe, is replaced by a steady horizontal current from the surrounding cooler atmosphere.**

The ascending air, having reached a stratum of equal density with itself, ceases to move upward; but, if still pressed upon by a current from beneath, it is diffused horizontally in all directions. At length, gradually sinking, it may help to feed the horizontal current flowing towards the region of greatest heat, thus completing a circuit which will be repeated as long as the inequality of temperature continues.

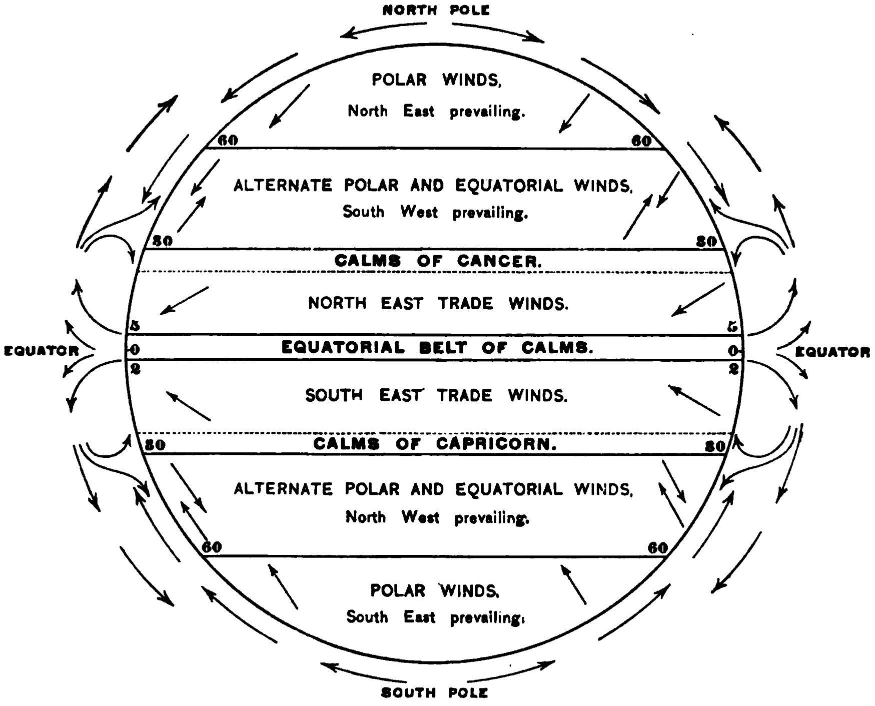

FIG. 32. NORMAL CIRCULATION OF THE ATMOSPHERE.

It is evident that, if the inequality of temperature be constant, the resulting circulation will be constant also; but if the overheating of a given region be only temporary, the motion will cease as soon as the lighter air has all taken its position above the heavier, and the equilibrium is restored throughout the strata to which the disturbance extended.

### II. General Circulation of the Atmosphere.

1. Winds are movements of the atmosphere caused by a disturbance of the equilibrium of its particles, the tendency of the motion being to restore that equilibrium. The disturbances are mainly occasioned by differences in temperature, and in the amount of vapor held in suspension by the air.

Winds may be grouped in three *classes;* namely, *constant, periodical,* and *variable* winds. The first class embraces the trade winds of tropical latitudes. The second includes the diurnal land and sea breezes, and the monsoons or season winds, occurring chiefly in tropical regions. The variable winds are more temporary and local, and characterize especially the temperate and high latitudes.

Winds are named from the points of compass whence they come.

2. General Atmospheric Currents. In the vicinity of the equator, where the average annual temperature is highest, — reaching 82° Fahr. and upward, — the atmosphere is at its minimum density; and the density gradually increases, with the diminishing temperature, from this region to the polar latitudes.

Set in motion by the ascending movement of the lighter equatorial atmosphere, the cooler and heavier air, all around the globe, flows towards this zone of maximum temperature. There, becoming, in its turn, rarefied by the intense heat, it ascends and finally returns, as an upper current, towards the poles.

Cooled by its expansion in ascending and its advance into colder latitudes, and contracted laterally in its progress towards the poles, this upper return current gradually descends, reaching the surface of the Earth somewhat beyond the tropics.

Thence a part returns towards the equator, the remainder continuing towards the poles, partly in the upper air, and partly as a surface current. The latter is more or less in contact with, and opposed by, the current setting from the poles towards the zone of greatest heat.

Hence from the permanent inequality in the distribution of heat in the tropical and polar regions, there results, in each hemisphere, a constant circulation of the atmosphere consisting of (1) an *ascending current,* in the zone of highest average temperature; (2) a *polar current* flowing upon the surface, from each pole towards the equator; and (3) a *return current* flowing from the equator towards each pole, partly in the upper air and partly on the surface, and supplying the constant drain of the polar current.

***The above diagram* is designed to illustrate this normal circulation of the winds. The arrows parting from the circumference of the circle, on each side of the equator, represent the ascending current in the region of greatest heat. This region is designated, for reasons given below, the equatorial belt of calms.**

**The polar current, which replaces the ascending air, is represented by the arrows pointing from the poles; while those pointing towards the poles represent the return currents.**

**The arrows within the circumference show the direction of the prevailing winds in the different zones, the figures indicating latitudes. Within the tropics the winds are directed westward and towards the equator. Beyond the tropics winds blow both towards and from the equator; while near the poles the polar winds predominate. Belts of calms occur where the return-trade descends from the upper air.**

3. Direction of Polar and Return Currents. Were the Earth at rest, and its surface uniform, these currents would doubtless follow the meridians to and from the equator. But the *rotary motion*[1] common to both the terrestrial globe and its atmosphere, causes the polar currents, as they near the equator,

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[1] See explanation of the direction of marine currents, page 65.

to turn more and more towards the west; hence they become northeasterly winds in the northern hemisphere and southeasterly in the southern. The return currents, on the contrary, advancing from equatorial to polar latitudes, are deflected towards the east, becoming southwesterly winds in the northern hemisphere and northwesterly winds in the southern hemisphere.

Again, the *continental reliefs*, and the relative positions of the land-masses and oceans, cause many local modifications in the direction of these general currents.

4. WIND ZONES. The general law of atmospheric circulation just noticed, gives rise to three distinctly marked wind zones, on each side of the Equator; namely: — (1) the zone of *constant winds*, extending to latitude 25° or 30°; (2) the zone of *variable winds*, with alternate polar and equatorial currents dominating, extending thence to latitude 60°, or near the polar circles; and (3) the zone of prevailing, though not constant, *polar winds*. (See Fig. 32, and the *Map of the Winds*, pages 80, 81.)

## III. Trade Winds and Calms.

1. TRADE WINDS. The constant, gentle, northeasterly and southeasterly winds, occupying a belt of about 20° of latitude on each side of the Equator, are designated the *trade winds*.

It was this constant and gentle wind which carried the navigator Magellan across the Pacific, and gave this ocean the name it has since retained; and which subsequently bore the Spanish treasure-ships, from the Mexican and Peruvian ports, to their destination in the Philippine Islands. The same unchanging westerly wind, observed in the Atlantic by the companions of Columbus, filled their minds with the fear that they could never accomplish a homeward voyage.

The trades blow with entire regularity only upon the open sea, the course and character of the winds elsewhere being modified by the continental reliefs or other local influences. The continents, on account of the elevation of their surface, partially intercept the general atmospheric currents, and, being also more heated than the adjacent oceans, they modify, or even overcome, the trades in their immediate vicinity.

Owing to this disturbing influence, the trades, both in the Atlantic and the Pacific, begin to blow regularly only at a considerable distance west of the continents. Thence they sweep, without interruption, over the ocean basins, at a nearly uniform rate of from 15 to 18 miles per day. In the northern half of the Indian Ocean the trades are suspended entirely during the northern summer, but resume their sway in winter. (See *Monsoons*, page 78.)

2. EQUATORIAL CALMS. The *boundary* between the northeast and southeast trades, is formed by the zone of the ascending current, from 4° to 6° in breadth, adjacent to the thermal Equator. The mean position of this zone is, in the Atlantic, between 3° and 9° north latitude; in the Pacific, between 4° and 8° north. In the continents it is usually found between 3° south, and 4° north latitude.

Here the ascending current overpowers the horizontal; and, as the upward motion is not perceptible to the observer, the atmosphere seems to be in a state of rest; hence this belt is designated the *Zone of Equatorial Calms*. (See Fig. 32, and *Map of the Winds*, page 80.)

The apparent equilibrium of the air, however, is very easily disturbed. Descending currents, sudden gusts of wind from any direction, whirlwinds, and hurricanes, are of frequent occurrence. Hence this belt is sometimes called the Equatorial zone of variable winds. In each great ocean this zone is considerably broader at the east than at the west. It is almost absent in the Indian Ocean.

3. TROPICAL CALMS. At the tropical limits of the trades, also (see *Map of the Winds*), there are zones of calms, designated the Calms of Cancer and the Calms of Capricorn. These, however, are less defined than the equatorial calms. They occupy a belt of a few degrees, in which the return current of the upper air, called the *return-trade*, first appears at the surface of the Earth; and where it divides, a part continuing towards the poles, and the remainder re-entering the trade zone and returning to the Equatorial calm belt.

4. OSCILLATION OF TRADES AND CALMS. The position of the trades, and of the intervening and adjacent calms, changes with the seasons, all advancing northward, and retiring southward, with the apparent motion of the Sun. The extreme northward position of the trades is reached in August and September, and the southward in March and April. (See diagram, *Limits of Trades*, in *Map of Winds*.)

In the oceans, the belt of Equatorial calms is north of the Equator in all seasons; and the Calms of Cancer are farther from the Equator than the Calms of Capricorn. These positions indicate a higher average temperature in the northern hemisphere than in the southern.

5. GENERAL LAND WINDS. The trades, as has been observed, lose their constancy of character under the influence of the continental reliefs; still, *prevailing easterly winds* occur, so far as known, on the great plains within the zone of trades. They are felt in a part of the Sahara; and in the basin of the Amazon they sweep, without interruption, across almost the entire breadth of the continent. Though gentle, in the east, like the trades of the ocean, their force increases considerably near their western limit.

Humboldt found at the base of the Andes, the east wind so strong that one could scarcely stand against it; and it is said that, on account of the constant east wind, the voyage up the Amazon, against the powerful current, is made quite as rapidly as that down the stream.

### ANALYSIS OF SECTION IV.

**I. Equilibrium of Atmosphere.**
  1. CONDITIONS OF EQUILIBRIUM OF AIR.
  2. DISTURBANCE OF EQUILIBRIUM.
    a. Effect of inequality of temperature.
    b. Resulting currents.
    c. Course of ascending air.
    d. Effect if inequality be permanent.
    e. Effect if inequality be temporary.

**II. General Circulation of Atmosphere.**
  1. WINDS.
    a. Definition.
    b. Classes.
  2. GENERAL CURRENTS.
    a. Zone of minimum density.
    b. Movement of air towards this zone.
    c. Movement of air from this zone.
    d. General currents resulting.
    e. Explanation of Fig. 32.
  3. DIRECTIONS OF GENERAL CURRENTS.
    a. Probable direction in absence of disturbing causes.
    b. Effects of the rotation of the Earth.
    c. Direction of polar currents.
    d. Direction of return currents.
    e. Other causes of modification.
  4. WIND ZONES.
    a. Number.
    b. Names and position.

**III. Zone of Trades and Calms.**
  1. TRADE WINDS.
    a. Definition. By whom first observed.
    b. Where occurring regularly.
    c. Place of beginning on oceans.
    d. Velocity.
    e. Trades of the Indian Ocean.

2. Equatorial Calms.
    a. Position in regard to trades.
    b. Breadth of calm belt.
    c. Cause of calm belt.
    d. Disturbance of equilibrium.
3. Tropical Calms.
    a. Position in regard to trades.
    b. Breadth and character of region.
4. Oscillations of Trades and Calms.
    a. Change of position caused how.
    b. When farthest northward.
    c. When farthest southward.
    d. Position of calm belt in regard to equator.
5. General Land Winds.
    a. Character of trades on land.
    b. Winds of Sahara, and Amazon basin.

## V. — WINDS (*continued*).

### I. Periodical Winds.

1. Monsoons. The name monsoon, from the Arabic word *moussim*, season, is applied to the periodical winds which replace the trades, in the northern half of the Indian Ocean, and in the adjacent portions of the Pacific. During the northern summer the wind blows from the southwest, during the opposite season from the northeast. The monsoons are due to the unequal heating, in different seasons, of the great land-masses which enclose the Indian Ocean.

The extent of land within the tropics, and the position of vast masses on opposite sides of the Equator, is such as to intensify to the greatest degree their disturbing influence upon the atmospheric currents. Only in the interior of the Indian Ocean, south of the Equator, does the trade wind blow regularly throughout the year.

During the *northern summer*, southern Asia, under the rays of the vertical Sun, becomes intensely heated; and the cooler and denser air of the adjacent ocean, and of southern Africa, flows towards it, producing the southwest monsoon, which lasts from April or May to September or October. The time of its beginning and its close varies in different latitudes, according to the time at which the sun is vertical in each.

During the *southern summer*, southern Africa being under the vertical Sun and intensely heated, the cooler air of the surrounding seas, and of southern Asia, flows towards it. This produces the northeast monsoon, which lasts from October or November to April. This monsoon is, in fact, only the regular northeast trade wind somewhat intensified.

A similar exchange takes place between Asia and Australia, but it is less marked, owing, perhaps, to the great islands lying between these continents.

The *period of transition* of the monsoons, in spring and autumn, is marked by sudden and violent gales, and terrific thunder storms. Destructive hurricanes, also, are of frequent occurrence.

*Narrow monsoon belts* occur in the Atlantic along the coast of Africa, and of Brazil; also on the Pacific coasts of North and South America (see *Map of the Winds*); but the phenomena they exhibit are of a much less striking character. On the African coast, in general, the winds blow from sea to land in summer, from land to sea in winter; on the Brazilian, the wind is from the northeast in summer, while in winter the southeast trade resumes its sway. The monsoons of the Pacific coast of America blow from the northwest and north during the southern summer; from the southwest and south during the northern.

2. Diurnal Land and Sea Breezes occur along all coasts, whether in the zone of trades or of variable winds; but the phenomenon is more strongly marked in the tropical regions, and in the summer of the temperate latitudes, because of the greater difference in the temperature of land and sea by day and by night.

During the hottest part of the day the air over the land frequently reaches a temperature of 100° Fahr., and even more, while that over the sea rarely rises above 80°. During the night the land radiates its heat with such rapidity that, towards morning, its atmosphere may be from 10° to 15° colder than that of the sea.

Soon *after sunrise*, the land being warmer than the sea, a sea breeze sets in, which increases in force until about three o'clock, when the difference of temperature is greatest. It then gradually diminishes until about sunset, when, the temperature of the land and sea having become equal, the atmosphere is at rest, the calm continuing for an hour or more.

Soon the land becomes cooler than the sea, and a gentle breeze from the former sets in. It increases in force as the night advances, becoming strongest a little before morning, when the temperature of the land is lowest; after which it rapidly dies away, and is succeeded by a calm, to be soon replaced by the sea breeze.

*Similar diurnal breezes* occur on the shores of all great lakes, and also at the foot of high mountains. The inclined surface of the mountain slopes has, while under the rays of the Sun, a higher temperature than the atmosphere, at corresponding altitudes, above the lowlands. Hence it becomes the natural channel for the ascending currents of warm air from the adjacent plains; and, consequently, a breeze ascends the valleys, towards the mountains, during the hottest part of the day.

3. Local Land Winds, of a peculiar character, occur more or less periodically, in different parts of the warm zones. The *Sirocco* of the Mediterranean shores, the *Khamsin* of Egypt, the *Samiel* or *Simoom* of Syria and Arabia, and the *Harmattan* of Guinea, are local names for a violent, hot and dry wind from the adjacent deserts.

In Guinea the desert wind blows from the northeast and east;

## QUESTIONS ON THE MAP OF THE WINDS. (See *Map*, *pages* 80, 81.)

Explain the coloring of this map. (See bottom of map.)

How is the direction of the winds indicated? (See explanation of arrows.)

How are periodical winds represented?

In which ocean does the belt of trades extend farthest from the equator?

On which shore of the Atlantic and the Pacific is the northeast trade belt broadest?

Where is the southeast trade belt broadest?

In what part of the oceans are the equatorial calm belts most extensive?

What name is given to the region of equatorial calms in the Atlantic?

What (see diagram in left hand margin) is the summer limit of the northeast trades in the Atlantic? The winter limit?

What are the summer and winter limits of the southeast trades?

In what part of the Indian Ocean do the trades blow with regularity?

Near what islands are the northeastern and southeastern limits of the Pacific monsoon region?

What are the directions of the monsoons in the seas adjacent to Australia?

What are their directions in the Asiatic and African seas?

In what part of the year does each current prevail?

Why? (See *Monsoons*, above.)

What are the directions of the winds in the Brazilian monsoon belt?

What winds prevail in the southern part of South America?

What is the direction of the winds on the west coast of South America?

When does each direction prevail?

What is the direction of the wind in the portion of the Pacific near the Isthmus of Panama?

What is the usual direction of the winds on the Atlantic shores of Africa?

What are the prevailing directions of the wind between the parallels of 30° and 60°?

How do these winds differ in character?

What is the direction of the polar winds in eastern North America and eastern Asia?

In western Asia, Europe, and northwestern North America?

What causes this difference in direction? (See page 79, Topic II., 3.)

What is the direction of the prevailing winds in the Arctic seas?

What is the position of the hurricane region of the New World?

Where are the hurricane regions of the Old World?

Where do the typhoons of the Asiatic seas originate? What is their course?

Where do the Mauritius hurricanes start, and in what direction do they move?

What is the place of origin of the West India hurricanes? What is their course?

What (see diagram in the right hand margin) are the intervening directions in a change of the wind, in the northern hemisphere, from northeast to southwest?

What is the effect of this change on the thermometer and the barometer?

What is the order and effect of a change from southwest to northeast?

What is the order and effect of a change, in the southern hemisphere, from a northwest to a southeast wind?

From a southeast to a northwest wind?

on the Mediterranean shores, from the southeast, south, and southwest; in Syria, from the south and southeast; and in Arabia, from the interior towards all points of the compass. The Sirocco, advancing across the Mediterranean, is felt in Sicily and Italy; and is known in southern Spain as the Solano or Levanter.

The name, Khamsin, meaning fifty, indicates the length of the season, — about fifty days, including the month of May and a part of April and June, — during which this wind may blow. Simoom means hot as well as poisonous. These desert winds are not continuous, but *occur at intervals* during the two or three months of greatest heat, lasting from one to fifteen days at a time. They usually blow in successive blasts, which differ in temperature, sometimes by more than 20° Fahr., and alternate with great rapidity. Dry, laden with the impalpable dust of the desert, and subject to such rapid alternations of temperature, they are exceedingly oppressive and exhausting to the human system, and not infrequently cause death by prostration.

The *Etesian Winds* are northeasterly and easterly winds which blow, during the latter part of summer, over Greece, the Archipelago, and the Mediterranean, towards the continent of Africa. They commence near the middle of July, when the heat is greatest, and continue until September, blowing only in the day-time.

The *Northers* of Texas are violent, cold, dry winds, which descend from the upper air, and occur chiefly in winter. They sweep over Texas, Louisiana, and the table-lands of Mexico, sometimes carrying their cold blasts even to the Antilles, where they present a striking contrast to the gentle and genial trade winds.

### II. Zone of Variable, or Alternating Equatorial or Polar, Winds.

1. PREVAILING CURRENTS. Within this zone, which extends from the vicinity of the tropics to the polar circles, the winds are not periodical, but blow during the year from every quarter of the horizon, without apparent order. Two general currents, however, the polar winds and the return-trades, predominate to such an extent that they may be considered the prevailing, or *normal currents*, of these latitudes.

Differing in temperature, and flowing side by side, or one above the other, but in opposite directions, they constantly encounter each other and struggle for the mastery. Their conflicts produce the frequent storms which characterize these zones; and the displacement of the one by the other always involves a marked change of weather. The return-trade brings heat, and clouds or rain; but the polar winds bring cold, dry weather, a bracing air, and a clear sunny sky.

The *other winds* blowing in these zones are either the transition winds, which occur during the displacement of one current by the other; or are the result of the deflection of these normal currents, by mountain ranges or other peculiarities of the continental reliefs.

2. SUCCESSION OF WINDS. The return-trades and the polar winds usually displace each other in an order indicated by Prof. Dove, and called by him the *law of the rotation of the winds.* This order of succession must not be confounded with the veering of the wind from point to point in a revolving storm, which has a different origin. (See *Revolving Storms*, page 82.)

*In the northern hemisphere*, generally, when the return-trade is displaced by the polar current, the wind blows successively from the west, the northwest, and the north, and settles in the northeast. In eastern North America, however, it settles in the northwest. (See Topic 3, below.) When the polar wind is displaced by the return-trade, the successive changes are to the east, southeast, south, and finally to the southwest. (See diagram in *Map of Winds.*)

*In the southern hemisphere* the order of transition is reversed, as is also the character of the currents. The northwest wind is the warm, moist return-trade; while the southeast is the cold, dry polar wind. The transition is from the northwest by the west, southwest and south to the southeast; and from the southeast by the east, northeast, and north, to the northwest.

The *effect of the transition* of the winds is manifest, both in the density and the temperature of the air. When the return-trade blows, the air being warm, moist and light, the thermometer is high and the barometer low. When it is displaced by the polar current, the thermometer falls and the barometer rises.

3. The STARTING POINTS OF THE POLAR WINDS are in the centres of lowest temperature, on the Arctic shores of Asia and North America. (See *Map of Temperature*, pages 74, 75.)

The *expansion of these two continents* at the north is such that a great extent of land lies in the immediate vicinity of the Arctic circle. This large area of Arctic land, combined with the long nights of a winter lasting nearly or quite half the year, converts the northern regions of Asia and North America into vast refrigerators, where the atmosphere, during the northern winter, is reduced to its minimum temperature and its greatest density.

From here the *cold, heavy air* presses towards the oceans at the east and the west, and the more southerly warm lands. Hence *Eastern Asia* and *North America*, especially in high latitudes, receive their coldest winds from the northwest and north; while *Western Asia* and *Europe* receive them from the northeast.

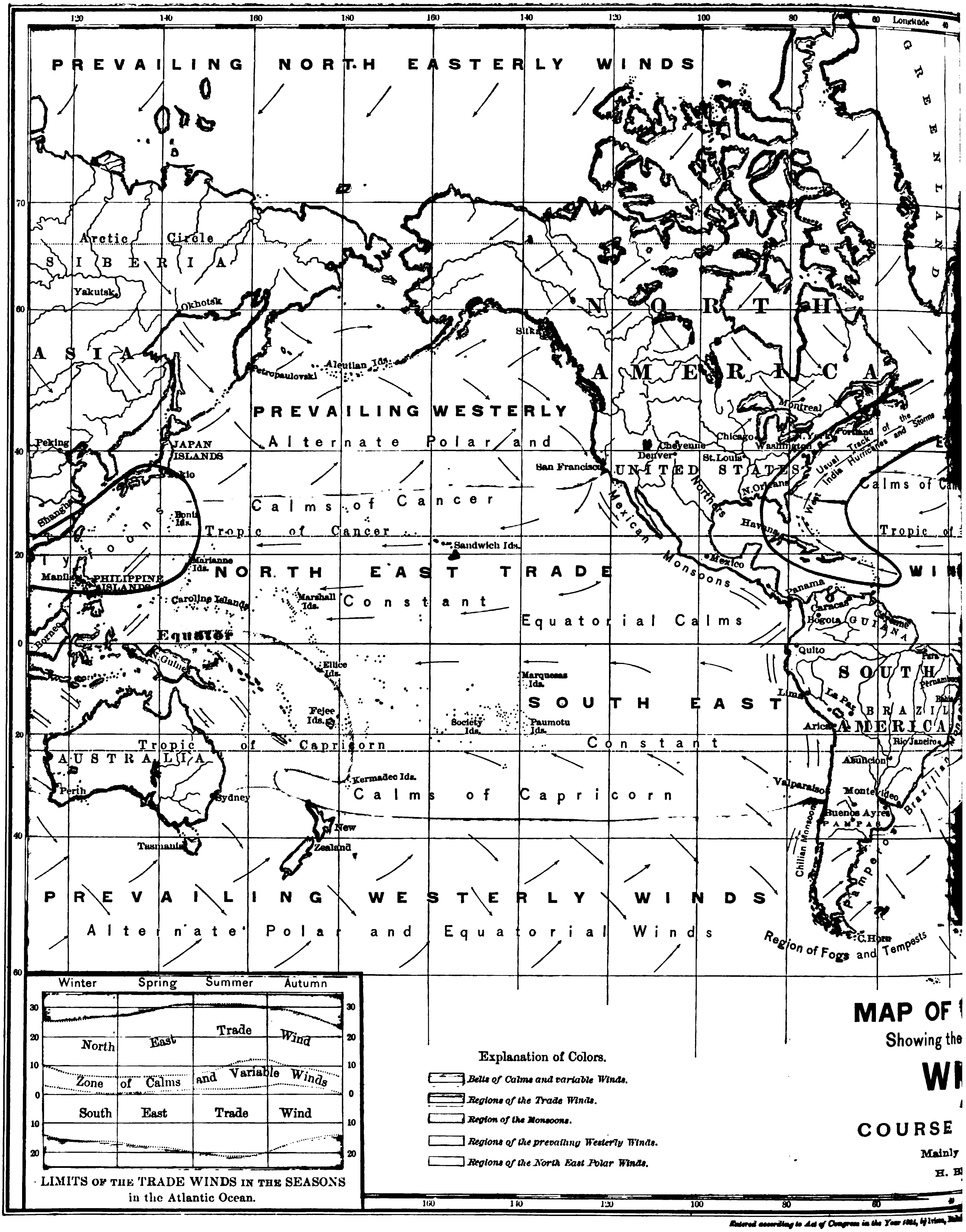
As the *cold air advances towards* the equator, and falls increasingly under the influence of the Earth's rotary motion, it tends more and more to become everywhere a northeast wind. But *in North America* the great barrier of the Rocky Mountains, which is highest in the middle latitudes, turns it out of its southwesterly course, and deflects it towards the southeast; hence throughout our Atlantic seaboard, even to the sub-tropical regions, the cold, dry winds are from the northwest. (See the *Map of the Winds.*)

As the *sun advances northward* in the spring, his genial beams impart a constantly growing warmth to the Arctic lands; and the rapidly increasing length of the days accelerates the change from a low to a high temperature. Thus the fountains of the cold winds are gradually dried up; the pressure of the northern air is diminished; and, during the summer, the warm gentle return-trades have almost undisputed sway nearly to the Arctic circle.

4. RANGE AND EFFECTS. The *polar currents*, having their origin in the Arctic lands, take their course, in general, over the surface of the continents, while the *return-trades* prevail upon the oceans. This fact accounts for the low average temperature of the interior of the continents, in middle latitudes, in comparison with that of the oceans, as indicated by the isothermal lines.

In the middle and northern portions of the zone of variable winds, the return-trades are the *dominant winds* during the summer, the polar winds during the winter. The *period of transition*, occupying several weeks following the equinoxes, is one of almost incessant conflict; hence the severe storms, and frequent changes of wind and weather which characterize those seasons of the year.

The *final establishment* of the return-trade, with its genial temperature and fertilizing showers, ushers in the summer; its final retreat before the polar winds, toward the close of the year, opens the winter. The *continuance* of the return-trade beyond its average time of displacement produces a "late autumn," and that of the polar winds, a "late spring."



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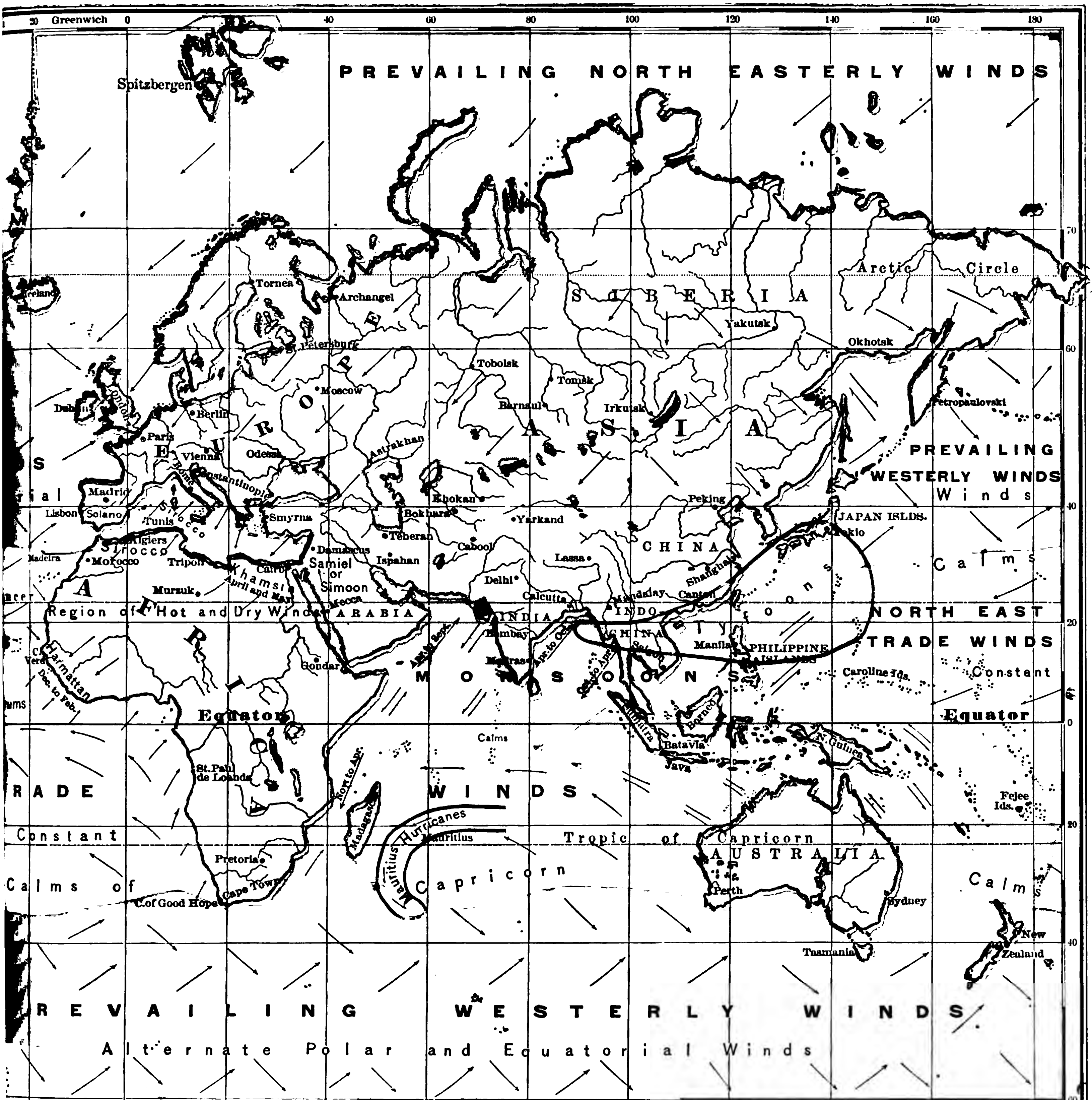

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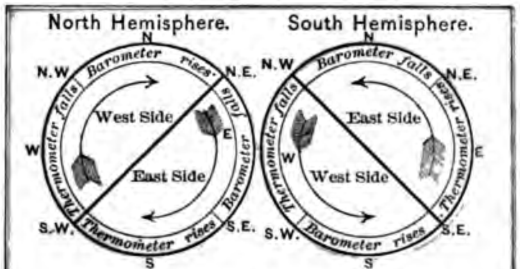
### Explanation of Arrows.

*The Arrows show the direction of the Winds. The head marks the point of the compass towards which the Wind moves; the opposite end that from which it blows.*

*Thus* ↘ *indicates a North West Wind blowing towards South East.*

↗ *indicates a South West Wind blowing towards North East.*

✕ ═ *Monsoons, or Season Winds, blowing periodically in one or the other direction.*



NORMAL SUCCESSION OF WINDS
and their effect on the Thermometer and Barometer.

& Co., in the Office of the Librarian of Congress at Washington, D.C.

## ANALYSIS OF SECTION V.

**I. Periodical Winds.**

- 1. MONSOONS.
    - a. Definition, direction, and cause.
    - b. Monsoons of Indian Ocean explained. Transition.
    - c. Minor monsoon belts. Position and character.
- 2. LAND AND SEA BREEZES.
    - a. Where occurring and why.
    - b. Daily alternation of temperature within the tropics.
    - c. Sea breeze, when and how caused. Land breeze.
    - d. Inland diurnal breezes.
- 3. LOCAL PERIODICAL WINDS.
    - a. Desert winds. Names and character. Directions. When and how occurring. Effects.
    - b. Etesian winds. Northers.

**II. Zone of Variable Winds.**

- 1. PREVAILING CURRENTS.
    - a. Character of winds in this zone.
    - b. Normal currents of this zone.
    - c. Effect of juxtaposition and opposite directions.
    - d. Character of other winds.
- 2. SUCCESSION OF WINDS.
    - a. Law of rotation signifies what. By whom discovered.
    - b. Order of displacement in northern hemisphere.
    - c. Order of displacement in southern hemisphere.
    - d. Effects of transition how manifested.
- 3. STARTING POINT OF POLAR WINDS.
    - a. Effect of expansion of lands in northern regions.
    - b. Atmosphere of northern lands in winter.
    - c. Motion of cold, heavy air.
    - d. Direction of winds in eastern Asia and North America.
    - e. Direction of winds in western Asia and Europe.
    - f. Effect of approach of current to equator.
    - g. Exception in North America.
    - h. Effect of advance of sun northward.
- SWEEP OF PREVAILING CURRENTS.
    - a. Path of polar winds.
    - b. Path of return trades.
    - c. Effect on comparative temperature of continents and oceans.
    - d. Dominant winds in different seasons.
    - e. Period of displacement.
    - f. Effect of final establishment of either current.
    - g. Effect of unusual prolongation of either.

# VI.—REVOLVING STORMS.

## I. Introduction.

When currents of air, moving in different directions, encounter each other, they produce a rotary motion in the atmosphere, such as is seen in the small whirlwinds which often lift up the dust of our streets in summer. Such a movement on a grand scale is a revolving storm or *cyclone*,[1] to which various local names are given. When the conflicting currents of air are of very different temperatures, these storms are usually accompanied by the condensation of vapor, producing rain, snow, or hail, and not infrequently by vivid electrical discharges.

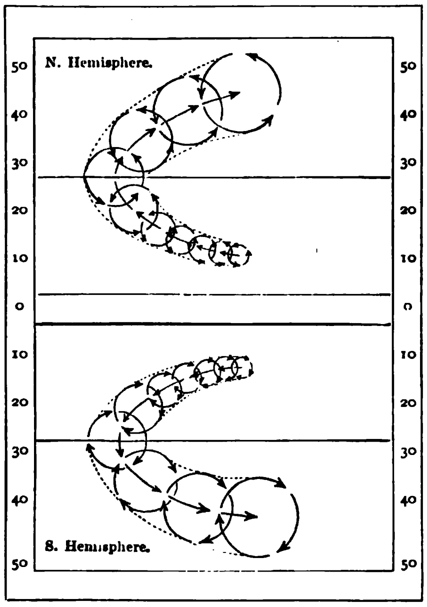


FIG. 33. COURSE OF CYCLONES.

*Cyclones vary* in the nature and violence of their phenomena, according to their immediate cause. The most remarkable for violence, and for the regularity of their course, are the *hurricanes* of the West Indies, and of Mauritius in the Indian Ocean; the *typhoons* of the South China Sea; and the *cyclones* of the Gulf of Bengal.

The *peculiar position* of these great cyclone regions of the globe, at the southeast of the largest continent and under the tropics, seems to indicate that these storms are the result of a conflict, in the upper air, between the general winds of the temperate and tropical zones, intensified by the disturbing influence of the great land masses.

## II. Law of Storms.

1. MOTIONS. Observations upon the winds and the pressure of the air, during cyclones, have been collected with great care and industry by Mr. Redfield of New York, Gov. Reid of Bermuda, Piddington of Calcutta, and Professor Dove of Germany. They all go to prove that, in these storms, the air rotates with great velocity, around a centre where calm prevails and the barometric pressure is least.

NORTH HEMISPHERE.

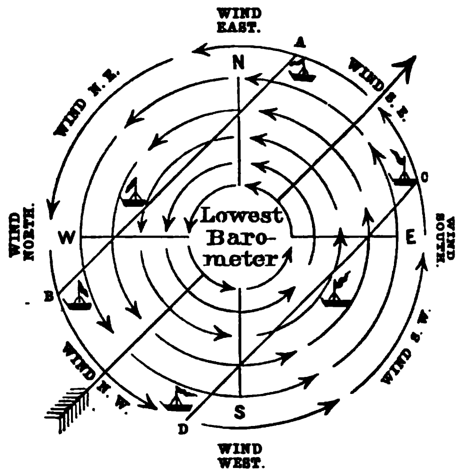


FIG. 34.

SOUTH HEMISPHERE.

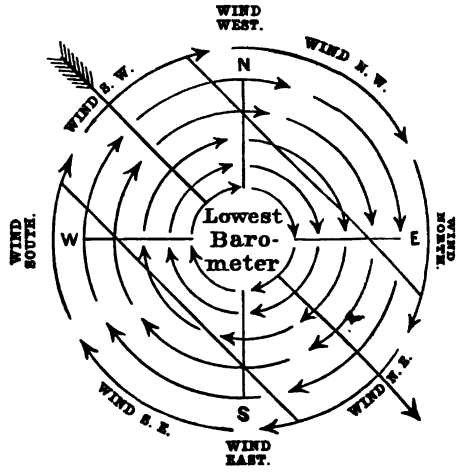


FIG. 35.

STORM CARDS.

Everywhere, on opposite sides of this centre, the wind blows from opposite directions; while the storm itself has a rapid progressive motion, and always advances from lower to higher latitudes.

In the *northern hemisphere* the rotary motion is from right to left, or contrary to that of the hands of a watch; while the progressive motion, within the zone of trades, is towards the northwest, and beyond that zone, towards the northeast. (See Fig. 33.)

In the *southern hemisphere* the rotary motion is from left to right; the progressive, in the zone of trades, is towards the southwest, and beyond that limit, towards the southeast.

The progressive motion, therefore, diverges slightly from the direction of the trade-winds within their limits, and follows that of the return-trades in the zone of variable winds. Hence it would seem to be connected with the general currents of the atmosphere.

2. ORIGIN AND PROGRESS. The cyclones usually *begin* within the tropics, but extend far into the temperate regions, where they gradually spend their force. The *West India cyclones*, called hurricanes (see *Map of Winds*), generally originate in the eastern Antilles, moving northwestwardly to the coast of Florida. About the limit of the trades, they turn nearly at a right angle, and sweep over the eastern coast of North America

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[1] From the Greek *kuklos*, a circle.

and the adjacent waters of the Atlantic; then crossing the ocean, they reach western Europe, beyond which they finally expire.

The *Mauritius hurricanes* start in mid-ocean, south of the Equator, move southwestward, sweeping over the islands of Mauritius and Reunion, and turn southeastward at the limit of the trades. The *typhoons*, originating in the tropical seas of India and China, move with the monsoons within the zone of trades, turning northeastward beyond that zone.

A familiarity, on the part of navigators, with the Law of Storms, will enable them to steer out of the track of a cyclone; for by observing the direction and veering of the wind, it can be known into what part of one a vessel is entering.

In the *northern hemisphere*, within the tropics, if the wind strikes a ship from the northeast, and veers to the north, the centre of the cyclone must be to the southeast; and as the storm advances towards the northwest, a southwesterly course will presently carry the vessel beyond its limits. Within the temperate regions, where the storm advances towards the northeast, the course of the vessel, under the same circumstances, must be towards the northwest. (See *Storm Cards*, Fig. 34, 35.)

In the *southern hemisphere* a northwest wind, veering to the north, shows the centre of the storm to be southwest of the ship. Her course, therefore, should be to the northwest within the tropics, and to the northeast in the temperate regions.

3. EXTENT AND PERIOD. All these storms alike, cover only a small area at their point of origin, but their violence is extreme. As they advance their circle gradually enlarges, while their fury diminishes.

The West India hurricane of 1839 had, in the Antilles, a diameter of 300 miles, which increased to 500 at the Bermudas, and 800 on the parallel of 50° north latitude.

Cyclones occur most frequently soon after the Equinoxes, at the time of the transition of the seasons and the general winds. According to Poey, out of 365 which desolated the West Indies between the years 1493 and 1855, two-thirds of the whole number occurred between August and October.

4. ASPECT. Except the great volcanic eruptions and earthquakes, no natural phenomenon is more awe-inspiring than these tremendous tempests. The portentous calm, and lurid sky which precede the bursting of the storm; the profound obscurity which follows the descending clouds; and the extreme violence of the wind, — uprooting whole forests, overthrowing the most solid edifices, sinking the largest ships in a few moments, or uplifting them bodily to break them on the shore, covering the Earth throughout its course with ruin and desolation, — place the cyclones among the long-remembered events whose recurrence is dreaded by all.

WATERSPOUTS.
Observed in the Mediterranean, near Sicily, on the 27th of June, 1827.

5. NORTHEASTERS. The great northeasterly winter storms of our latitudes, are but the left, or western, half of a revolving storm. Hence it is easy to understand why the wind, though blowing from the northeast, is felt at Washington and Philadelphia earlier than at New York and Boston.

Suppose the storm first strikes a place with a southeast wind, as at the point A in Fig. 34, in the *western half* of the storm. As it advances northeastward, passing over the point A, on the line A B, the wind blows successively from the east, northeast, north, and intermediate points, finally reaching the northwest (as at B). Then the storm ends, leaving the weather clear and cold.

In the *eastern half* of the storm (as at C, Fig. 34), the wind blows successively from the southeast, south, southwest, west, and intermediate points, the storm ending as before with a northwest wind. As the storm advances from southwest to northeast, the more southerly and westerly places are necessarily the first to feel its force.

If the *centre* of the storm passes over a place, the southeast wind, which blows continuously during the first half, is followed by a calm, with low barometer. After this lull the northwest wind sets in abruptly, and blows until the storm is over.

### III. Tornadoes and Water-Spouts.

1. THEIR NATURE. Tornadoes and water-spouts repeat on a small scale, though with scarcely less violence, the phenomenon of the cyclones.

When opposing winds of different temperatures meet in the upper atmosphere, a whirling motion is produced, drawing down the cold air above, and a vast amount of vapor is condensed into a thick black cloud.

Soon, with increasing rapidity of rotation, the whirling mass takes the shape of a vast funnel, descending lower and lower into the quiet atmosphere beneath, drawing up in its vortex all objects within its path. On its track, varying from a few yards to a quarter of a mile in width, trees are uprooted, and houses unroofed or carried up into the air by the fearful power of the tornado.

When passing over deserts the tornado lifts up the loose sand of the surface, which it often transfers to a distance, letting it fall as it spends its force, forming mounds and hillocks. In this way the aspect of the surface of the deserts is often materially changed.

A tornado passing into the sea forms a *water-spout*. The descending funnel, approaching the surface of the water, lifts up a column of spray, which joins in its rotary motion, thus binding together, as it were, the clouds and the sea.

The above illustration, drawn from nature, represents a number of water-spouts, which occurred within a short distance from each other, showing the various forms and stages of this remarkable phenomenon.

2. Origin and Course. Tornadoes, like cyclones, usually move with the return-trades. They seem to be due to a conflict, in the upper air, of local currents, encountering each other in an atmosphere highly charged with vapors. A great number originate over the vast plains west of the Mississippi River, and sweep towards the northeast, spreading desolation along their narrow track.

### ANALYSIS OF SECTION VI.

- **I. Introduction.**
    - a. Cause of rotary movement in the air.
    - b. Cyclone. Definition. Significance of term.
    - c. Accompanying phenomena.
    - d. Difference in cyclones.
    - e. Examples of cyclones.
    - f. Position of cyclone regions. Conclusion therefrom.
- **II. Law of Storms.**
    - 1. Motion.
        - a. Character and centre.
        - b. Winds on opposite sides of centre.
        - c. Cyclones of northern hemisphere.
        - d. Cyclones of southern hemisphere.
        - e. Connection with general winds.
    - 2. Origin and Progress.
        - a. Latitude of beginning.
        - b. Course of West India hurricanes.
        - c. Course of Mauritius hurricanes.
        - d. Means of escaping from these storms.
    - 3. Extent and Period.
        - a. Area in different parts of course. Example.
        - b. Time of most frequent occurrence.
    - 4. Aspects.
        - a. Impression created.
        - b. Phenomena noted.
    - 5. Northeasters.
        - a. Character of these storms.
        - b. Changes of wind.
- **III. Tornadoes and Water-Spouts.**
    - 1. Their Nature.
        - a. Resemblance to cyclones.
        - b. How produced.
        - c. Form and effects.
        - d. Tornado on the desert. Water-spouts.
    - 2. Origin and Course.
        - a. Track of tornadoes.
        - b. Probable cause.
        - c. Place of origin. Direction.

## VII. — DISTRIBUTION OF VAPOR IN THE ATMOSPHERE.

### I. Humidity of the Atmosphere.

1. Evaporation. Water, whether in the sea or on land, is slowly transformed into invisible vapor, which, being much lighter than air — as 3 : 5 — rises, and is diffused through every part of the atmosphere. Thus the latter becomes the great reservoir of aqueous vapors.

The capacity of the air for the absorption of vapor increases with its temperature; but, at any given temperature, there is a certain limit beyond which it can receive no more. When filled to its utmost capacity it is said to be *saturated* with humidity, and the least lowering of the temperature causes a condensation of moisture in the form of dew, fog, clouds, or rain; but if the temperature is raised, the capacity for vapor being increased, absorption recommences.

As long as the amount of vapor present in the air is much less than is required for saturation, evaporation goes on rapidly, and the air continues to absorb the rising vapors. It is, therefore, called *dry* air.

When the air is nearly saturated, evaporation proceeds but very slowly; when saturation is reached, evaporation ceases, and the air is *moist* or *humid*.

From the following table it is evident that, by a simple change of temperature, the air may be changed from moist to dry, or the reverse, without any change in the absolute amount of vapor it contains.

The *weight of vapor* contained in a cubic foot of saturated air, at temperatures varying from 20° to 100° Fahr., ascertained by careful observation, is given in the following table : —

| Temperature of Air. | Weight of vapor in a cubic foot of saturated air. | Temperature of Air. | Weight of vapor in a cubic foot of saturated air. |
|---|---|---|---|
| 20° Fahr. | 1.30 grains Troy. | 70° Fahr. | 8.00 grains Troy. |
| 32° " | 2.13 " " | 80° " | 10.95 " " |
| 50° " | 4.09 " " | 90° " | 14.81 " " |
| 62° " | 6.15 " " | 100° " | 19.79 " " |

The *relative humidity* of the air is the ratio which the absolute amount of aqueous vapor it contains, bears to the amount required for saturation at the same temperature. The degree of moisture contained is expressed by the fraction of saturation.

If the air, at the temperature of 50° Fahr., contains but two grains of vapor to the cubic foot — one-half of that required for saturation — its relative humidity will be expressed by the fraction ½, or its equivalent 50 per cent; but if the temperature be raised to 70° Fahr., with no addition of vapor, the air will contain but ¼ of the amount required for saturation, and its relative humidity will be 25 per cent. If, on the contrary, the temperature be lowered, the relative humidity will be increased until saturation is finally reached and condensation begins, which, as is shown by the table, will not take place until the temperature is reduced to 32° Fahr.

2. Dew Point. The temperature at which saturation is complete, and the invisible vapor of the air begins to condense, is called the *dew point.* It is evident that, the less the relative humidity, the greater will be the difference between the temperature of the air and the dew point. In the above examples, the temperature of the dew point being 32°, that difference is respectively 18° and 38°.

Both the relative and the absolute humidity of the air may be ascertained by a simple experiment. Suppose the temperature of the air to be 70° Fahr., requiring, according to the above table, 8 grains of vapor to the cubic foot, for saturation. Place the bulb of a thermometer in a glass of water, gradually cool the latter with ice, and note the temperature at which moisture begins to appear on the outer surface of the glass. This is the dew point of the air, which we will suppose to be 50°. The number in the table opposite this temperature shows the absolute amount of vapor contained in the air, which is 4.09 grains to the cubic foot. This amount divided by 8, the amount required for saturation, gives 0.51, or fifty-one per cent., for the degree of the relative humidity.

Visible masses of vapor resting on, or near, the ground are called fogs; while those floating in the air at a considerable height are distinguished as clouds.

3. Forms of Clouds. *Clouds are classified* according to their forms, which depend mainly upon the mode of formation. The principal forms are the cirrus, feather, or curl-cloud; the cumulus, or heaped cloud; the stratus, arranged in long horizontal bands; and the nimbus, a dense, formless cloud, with ragged edges and the bottom breaking into rain-drops. Several intermediate forms also occur, among which the cirro-cumulus, or fleecy cloud, is most conspicuous. (See illustration, page 85.)

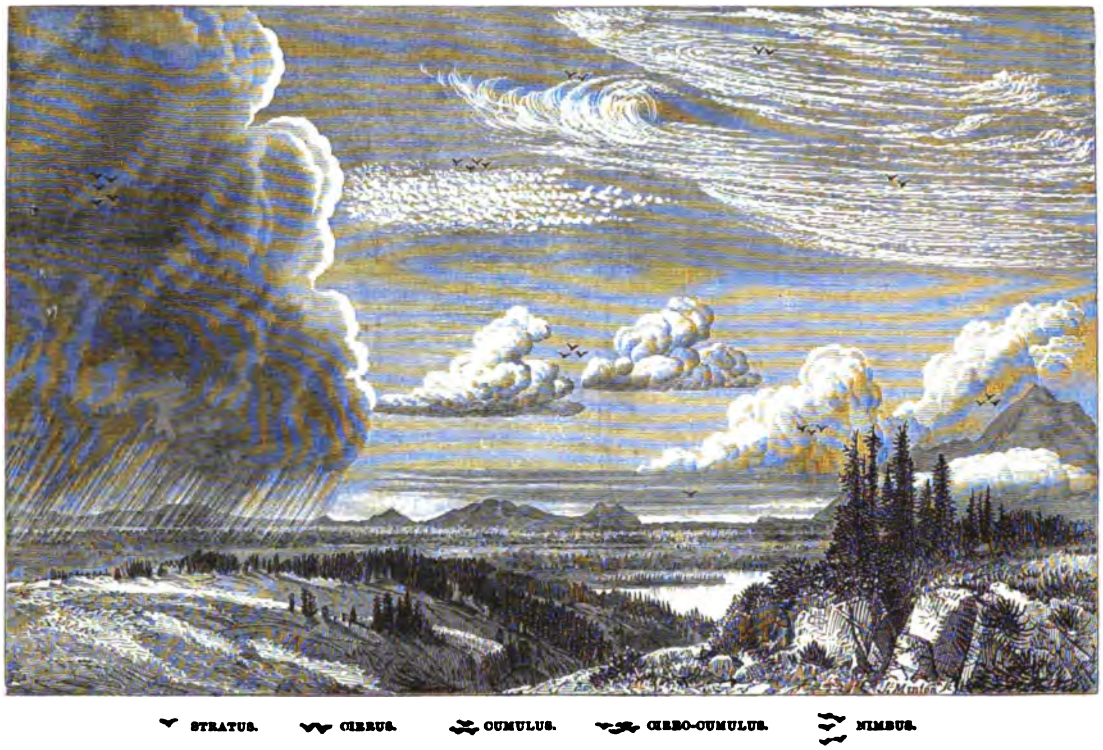
The *cirrus* and *cirro-cumulus* clouds are the highest, are mostly in the altitudes of perpetual frost, and are supposed often to consist of minute ice crystals. In temperate latitudes they are usually formed in, and move with, the upper air current, or return-trade, from the tropical regions.

The *cumulus* clouds are characteristic of the tropics, and of the summer days in middle latitudes, their height depending upon the relative humidity of the air. They are formed by local ascending currents, which carry a large amount of vapor into the cooler upper air. There the vapors are condensed, and are gradually heaped up into these heavy masses of sharply defined clouds, which look like vast snowy mountains. Their base is horizontal, and marks the height at which the dew point is reached and condensation begins.

The accumulation of vapors is often so great that these clouds form a column several thousand feet high. In this case the difference in the temperature and the electrical conditions of the upper and lower portions, is such that electrical discharges take place, accompanied by condensation of a portion of the cloud, forming a thunderstorm. (See page 89, II., 1.)

*Stratus* clouds are most frequently seen in the morning or evening, and are always low. They are formed by the descent of the higher clouds and vapors of mid-day, into the lower air, as the temperature decreases. They are more frequent in winter and summer than in the intermediate seasons.

The *nimbus* cloud is more dense and heavy than the others, which may all be transformed into the nimbus by a diminution of temperature. It is of a dark leaden hue, changing into gray. This is the most common form of cloud in polar latitudes; and, during the cold season, it is the most frequent of the temperate zones.



FORMS OF CLOUDS.

4. THE AVERAGE HEIGHT OF THE CLOUDS is greatest in the tropical latitudes, and in the summer of the temperate; and least in the polar regions, and in the winter of the temperate zones.

As *raindrops* constantly increase in size, by the accumulation of moisture from the air through which they fall, it is evident that their size will depend upon the height of the clouds whence they descend, as well as upon the rapidity of condensation. Hence *tropical rains* and *summer showers* fall in large, heavy drops; while drizzling rains, mists, and fogs are characteristic of cold latitudes, and of the cold season of middle latitudes.

## II. Condensation.

1. CAUSES OF CONDENSATION. Condensation and rain are mostly caused by the cooling of currents of warm air laden with aqueous vapors.

A *warm wind* starting from the tropics clear and dry, and advancing into cooler latitudes, continually diminishes in temperature. Hence, without receiving additional vapors, its relative humidity constantly increases until saturation is reached, when the air becomes moist and cloudy, and finally rain falls.

A *cold wind*, on the contrary, starting from the polar regions saturated with vapor and full of clouds, and advancing to warmer latitudes, has its capacity for moisture constantly increased. Hence it becomes at every step less humid, and its clouds dissolve, leaving the air clear and dry. Our northwesterly winds, and the Etesian winds, which bear the vapors of the Mediterranean into the Sahara, are examples of this change.

Thus warm winds, blowing towards cooler regions, bring rain; while cold winds, advancing to warm climates, bring fair weather and drought. When the two are *intermingled*, the temperature of the former is reduced, and cloudiness or rain is the result.

*Ascending currents* give rise to similar phenomena. The warm air, laden with vapors exhaled from the heated surface of land or sea, rising into the upper regions of the atmosphere, expands and becomes cool; and its vapors, condensing rapidly, return to the ground in copious showers. Thus are produced the rains of inter-tropical regions, and the summer showers of middle latitudes.

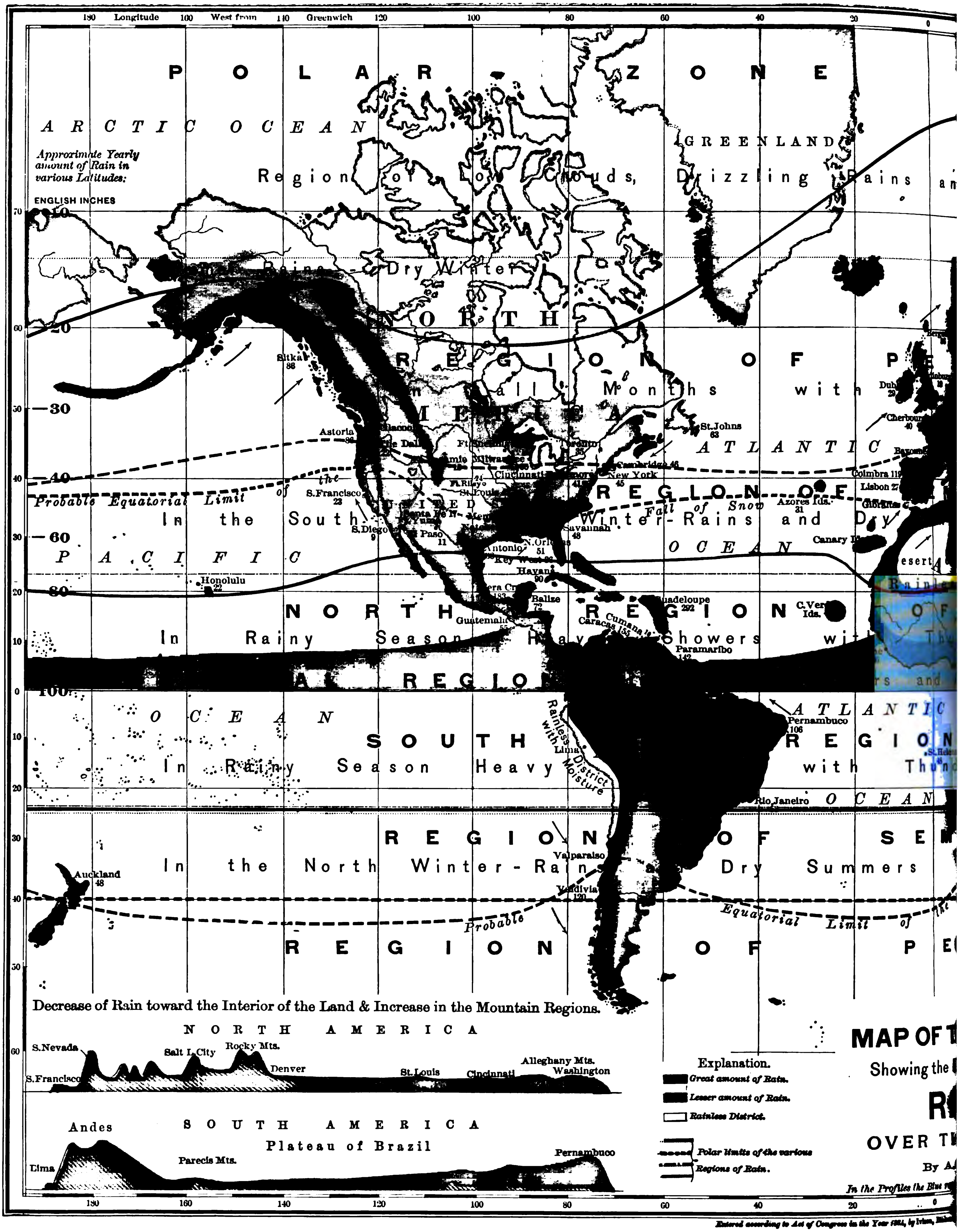
2. INFLUENCE OF RELIEF AND SURFACE. *Mountain chains*, in general, act as condensers, especially when lying across the path of warm winds. Upon the side exposed to the wind, the air is forced upward along the slopes, and its vapors are condensed into clouds, whence torrents of rain fall; while on the opposite side it descends, with increasing temperature, as a dry wind.

**Thus the *Andes Mountains*, intercepting the vapors borne by the southeast trades of South America, separate the moist plains and luxuriant forests of the Amazon and Paraguay basins, from the rainless and barren coasts of Peru and Bolivia. The *Sierra Nevada*, in California, and the *Cascade Range*, in Oregon, lying across the path of the warm return-trades, separate well watered and fruitful coast regions from a dry and barren interior.**

**The *Scandinavian Mountains*, in Europe, rob the southwest return-trade of its vapors, so that, though it brings rain in Norway, it is the fair-weather wind in Sweden. On the southern slopes of the *Alps* from 60 to 90 inches of rain fall anually, varying with the locality, while the northern slope receives but 35 inches. The *Himalaya Mountains* and the *Western Ghauts*, in India, interpose a like barrier to the vapors borne by the southwest monsoons, and occasion similar contrasts in the rainfall upon their opposite slopes.**

*Plateaus* usually receive less rain than other forms of relief, because the mountains, which form the borders of the greater number, prevent the vapors borne by the wind from reaching them. Again, the air resting upon these broad elevated surfaces, which absorb the powerful rays of the Sun (page 72, II., 2), is, in summer, warmer than the surrounding atmosphere; hence it tends to dissolve, rather than to condense, the vapors borne into it by lateral currents.

The *nature and covering of the soil* also has an influence upon the condensation of the vapor in the air. A barren region, with nothing to shield it from the burning rays of the sun, becomes intensely heated; and imparts to the superincumbent



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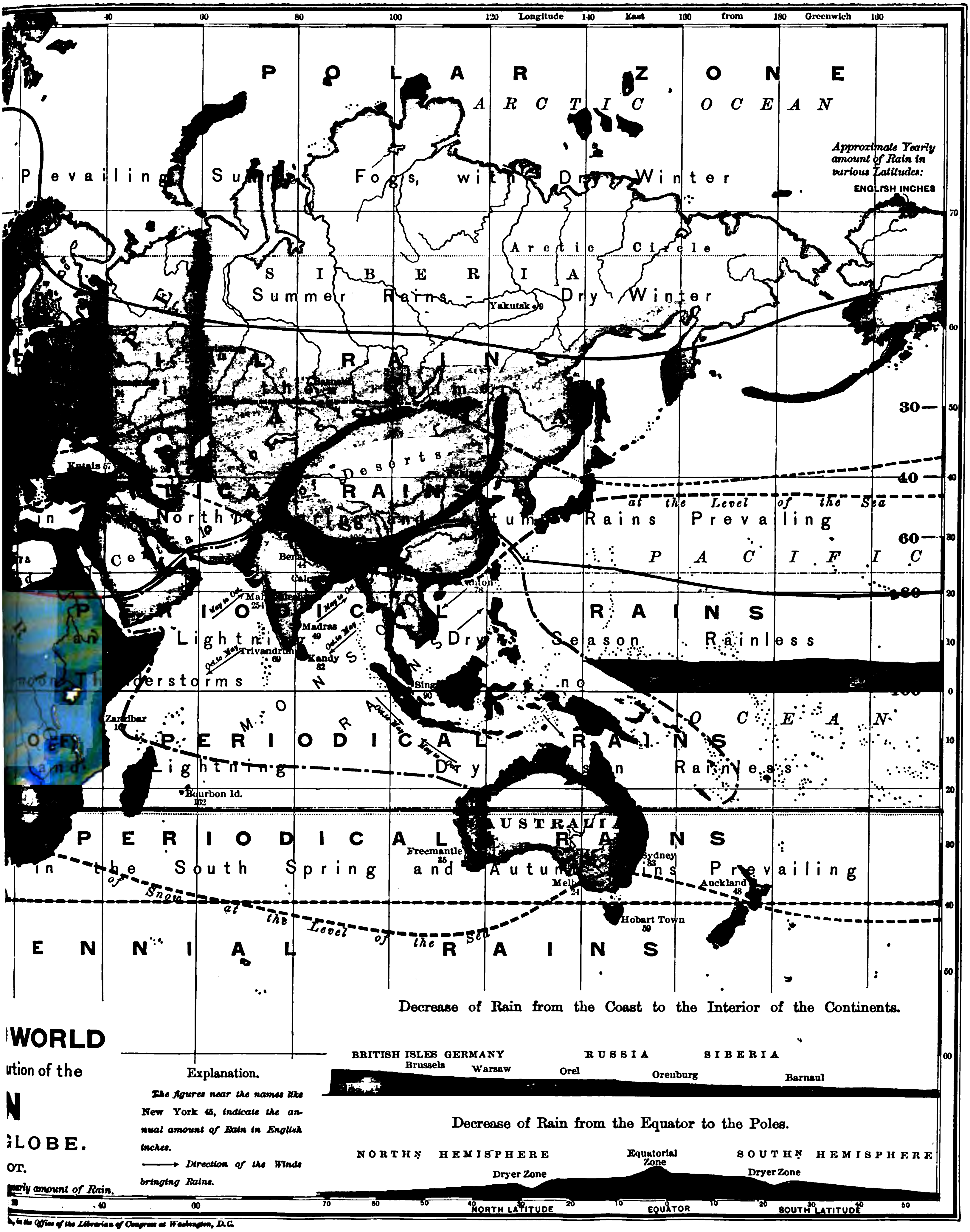


WORLD

ution of the

N

GLOBE.

OT.

yearly amount of Rain.

Explanation.

*The figures near the names like New York 45, indicate the annual amount of Rain in English inches.*

——→ *Direction of the Winds bringing Rains.*

, in the Office of the Librarian of Congress at Washington, D.C.

air so high a temperature as to dissipate all clouds which may float into it from the surrounding atmosphere. A covering of vegetation, on the contrary, shields the soil from the sun's rays, keeps its temperature lower, and promotes condensation.

Hence forests receive more rain than treeless regions similarly situated, while at the same time they check the evaporation of moisture from the soil, and favor the gradual percolation of the rain-water through the ground; thus they equalize the irrigation of the surrounding country, and augment the volume of its springs and rivers.

## III. Distribution of Clouds and Rain.

1. Laws of Distribution. Though the distribution of rain is much more liable than the temperature, to irregularities and extremes, dependent upon local circumstances, yet the following general laws hold good: —

(1) The *average quantity of rain falling annually* is greatest in the tropical regions, where the rapidity of evaporation, and the absolute amount of vapor in the air, are both extreme; and the average decreases gradually with increasing latitude.

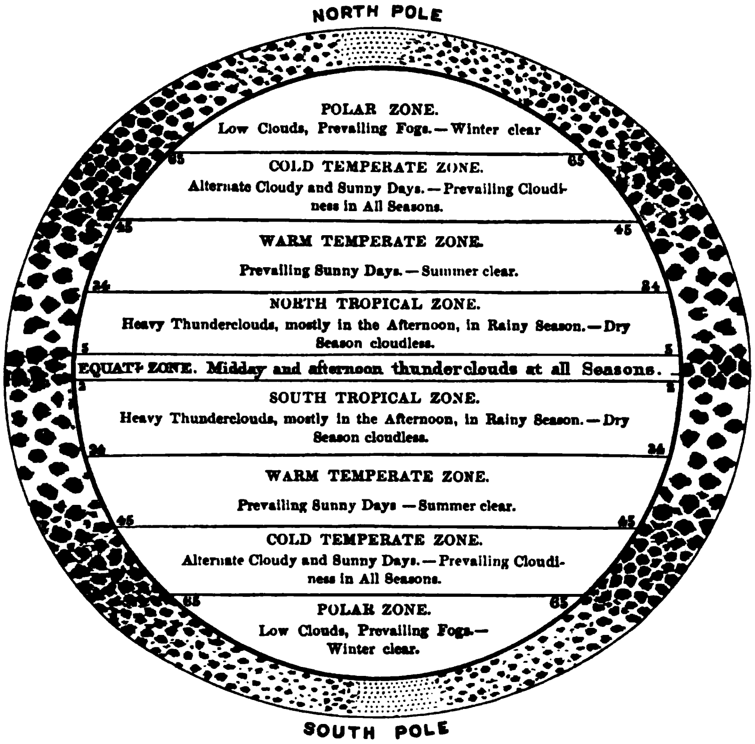

NORTH POLE
POLAR ZONE.
Low Clouds, Prevailing Fogs. — Winter clear
65
65
COLD TEMPERATE ZONE.
Alternate Cloudy and Sunny Days. — Prevailing Cloudiness in All Seasons.
45
45
WARM TEMPERATE ZONE.
Prevailing Sunny Days. — Summer clear.
24
24
NORTH TROPICAL ZONE.
Heavy Thunderclouds, mostly in the Afternoon, in Rainy Season. — Dry Season cloudless.
5
5
EQUAT. ZONE. Midday and afternoon thunderclouds at all Seasons.
5
5
SOUTH TROPICAL ZONE.
Heavy Thunderclouds, mostly in the Afternoon, in Rainy Season. — Dry Season cloudless.
24
24
WARM TEMPERATE ZONE.
Prevailing Sunny Days — Summer clear.
45
45
COLD TEMPERATE ZONE.
Alternate Cloudy and Sunny Days. — Prevailing Cloudiness in All Seasons.
65
65
POLAR ZONE.
Low Clouds, Prevailing Fogs. — Winter clear.
SOUTH POLE

FIG. 36. COMPARATIVE CLOUDINESS IN THE DIFFERENT LATITUDES.

The following TABLE, showing, approximately, the average annual rainfall of different latitudes, exhibits clearly the above law: —

| Latitude. | Inches of Rain. | Latitude. | Inches of Rain. |
|---|---|---|---|
| 0° (Equator) . . . . | 100 | 50° . . . . . . . . . | 30 |
| 20° . . . . . . . . . | 80 | 60° . . . . . . . . . | 20 |
| 30° . . . . . . . . . | 60 | 70° . . . . . . . . . | 10 |
| 40° . . . . . . . . . | 40 | 80° . . . . . . . . . | 5 |

(2) The *cloudiness* of the air and the *number of rainy days* in the year, increase gradually from equatorial to polar regions. (Fig. 36.)

Within the tropics, the average number of cloudy or rainy days in the year is only from eighty to ninety, and often much less. In the middle latitudes there are twice this number; and in the polar regions fogs and clouds reign supreme, except during the winter.

(3) Both, the *average rainfall* and the *number of cloudy or rainy days*, diminish gradually from the coasts to the interior of the continents.

The following TABLE shows the variation in rainfall and rainy days, in countries of the Old World, between 45° and 50° north latitude. (See diagram in *Map of Rains.*)

| Countries. | Average Rainfall. | Rainy Days. | Countries. | Average Rainfall. | Rainy Days. |
|---|---|---|---|---|---|
| British Isles . . . . . | 32 inches. | 156 | Hungary . . . . . . | 17 inches. | 111 |
| Western France . . . . | 25 " | 152 | Russia (Kasan) . . . . | 14 " | 90 |
| Eastern France . . . . | 22 " | 147 | Siberia (Yakutsk) . . . | 10 " | 60 |
| Germany, Cen. and N. . | 20 " | 150 | | | |

Observations in North America show a like diminution with increasing distance from the sea; but, on account of the free entrance of vapors from the Gulf of Mexico into the interior of the continent, the decrease, from the Atlantic westward, as far as the Mississippi, is less marked.

The moisture from the Mediterranean and the Indian Ocean, on the contrary, is intercepted by the moutain ranges composing the main axis of Asia-Europe, which form a great barrier near the southern shores. This fact, with the plateau character of Iran and Mongolia, accounts for the lack of moisture which dooms these countries mainly to the condition of a desert.

(By turning to the *Map of Rains* it will be seen that the great central zone of deserts, extending from the Atlantic — through the Sahara, Arabia, Iran, and Mongolia — nearly to the Pacific, lies in the interior of the greatest continental masses of the Old World.)

2. Rainfall of the New and Old World. The New World, which forms a comparatively narrow belt of land between two great oceans, receives, both in temperate and tropical regions, a larger average amount of rain than the Old World.

The average for the tropical regions of the New World is roughly estimated at 115 inches; while that of the Old, with its large and compact masses of land, is but 77, making the mean for the entire zone 96 inches. The average of temperate America is 38 inches; that of Asia-Europe, in temperate latitudes, is 34; making a mean of 36 for the entire zone. Eastern North America has an average of 40 inches of rain for 25 in western Europe, in corresponding temperatures.

## ANALYSIS OF SECTION VII.

**I. Humidity of the Air.**
- 1. Evaporation.
  - a. Process. Reservoir of vapors.
  - b. Capacity of air for absorbing vapor. Saturation.
  - c. Dry air. Moist air. Change from one to the other.
  - d. Saturation at different temperatures.
  - e. Relative humidity of air how expressed.
  - f. Changes of relative humidity.
- 2. Dew Point.
  - a. Definition.
  - b. Relation to relative humidity of air.
  - c. Humidity of the air ascertained how.
- 3. Forms of Clouds.
  - a. Classification.
  - b. Cirrus and cirro-cumulus clouds.
  - c. Cumulus.
  - d. Stratus.
  - e. Nimbus.
- 4. Average Height of Clouds.
  - a. Where and when greatest.
  - b. Where and when least.
  - c. Effect on size of raindrops.
  - d. Effect on character of rains.

**II. Condensation.**
- 1. Causes.
  - a. Condensation usually due to what.
  - b. Effect of passage of warm winds to cold regions.
  - c. Effect of passage of cold winds to warm regions.
  - d. Effect of intermingling of warm and cold winds.
  - e. Condensation by ascending currents.
- 2. Influence of Relief and Surface.
  - a. Condensation by mountain chains. Examples.
  - b. Condensation on plateaus.
  - c. Influence of barren soil.
  - d. Influence of forests.

**III. Distribution of Clouds and Rain.**
- 1. Laws of Distribution.
  - a. Of annual average rainfall.
  - b. Of cloudiness and rainy days.
  - c. Variation from coasts to interior.
- 2. Rainfall of New and of Old World.
  - a. Average in tropical regions.
  - b. Average in temperate regions.

## VIII.—RAIN IN DIFFERENT LATITUDES.

### I. Rain Zones.

Owing to the intimate relation which exists between the temperature, the winds, and the condensation of vapors, each of the great climatic zones of temperature and winds has also a distinct system of rains.

Within the *tropical regions*, which are characterized by uniform temperature, and trade winds or calms, the rains are occasioned by ascending currents, formed in the hottest part of the day or year. Hence the trade zones are zones of *periodical rains*.

In the *temperate and cold regions* the rains are mainly caused by the intermingling of cold and warm horizontal currents. This may occur at any time, but is most frequent in winter, spring, and autumn; consequently in these zones the rains are either *perennial* or only *partially periodical.*

### II. Rains of Tropical Regions.

1. In the Belt of Equatorial Calms, where there is a constant ascending current which reaches its greatest velocity and humidity in the hottest part of the day, there are nearly *daily rains*, occurring during the hours of greatest heat. (Fig. 37.)

In the morning the sky is clear, but towards noon masses of white cumulus clouds appear at different points, rapidly spreading and darkening, until the whole heaven is overcast, when the storm bursts. Vivid flashes of lightning traverse the blackened sky, accompanied by deafening thunder, and the rain falls in torrents for two or three hours. Then it ceases; the ascending current slackens; the remaining clouds, as they descend by their weight into the warmer air, are dissolved; and the night is cloudless.

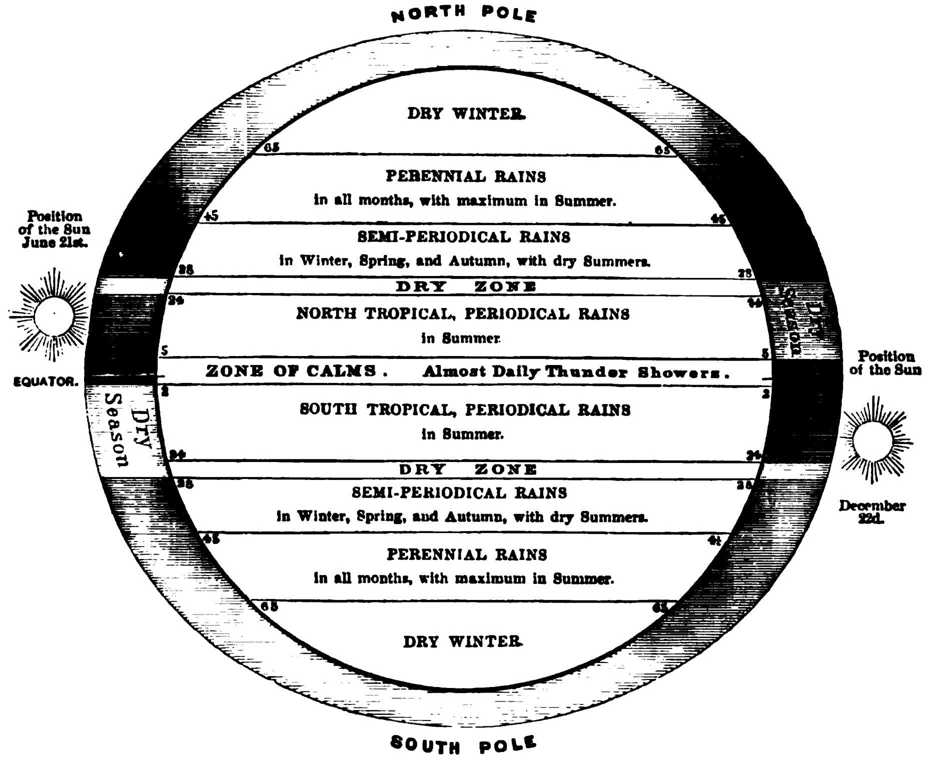

NORTH POLE
DRY WINTER.
65
65
PERENNIAL RAINS
in all months, with maximum in Summer.
45
46
SEMI-PERIODICAL RAINS
in Winter, Spring, and Autumn, with dry Summers.
28
28
DRY ZONE
24
24
NORTH TROPICAL, PERIODICAL RAINS
in Summer.
5
5
ZONE OF CALMS. Almost Daily Thunder Showers.
2
2
SOUTH TROPICAL, PERIODICAL RAINS
in Summer.
24
24
DRY ZONE
26
26
SEMI-PERIODICAL RAINS
in Winter, Spring, and Autumn, with dry Summers.
45
44
PERENNIAL RAINS
in all months, with maximum in Summer.
65
65
DRY WINTER.
SOUTH POLE
Position of the Sun June 21st.
EQUATOR.
Dry Season
Dry Season
Position of the Sun
December 22d.

FIG. 37. DISTRIBUTION OF RAIN IN THE DIFFERENT LATITUDES.

2. Within the Belts of Trades all the rain of the year falls in the few months during which the Sun is not far from the zenith, that is, in the summer, when the heat is so great that ascending currents take the place of the trades. This period is called the *rainy season;* the remainder of the year, the *dry season.* (See Fig. 37.)

(1) *Dry season.* While the trades blow without interruption, though abundant vapors may fill the air, there is nothing to cause condensation, except the cooling of the air during the night, when copious dews are deposited. Hence the sky preserves a constant serenity and a deep azure tint; and the atmosphere is cloudless, especially when the Sun is in the opposite hemisphere.

(2) *Rainy season.* As the Sun approaches the zenith the trades become irregular, being replaced by calms and fitful breezes from any direction. The sky assumes a whitish tint; clouds appear near the horizon, and vanish, as if driven by a swift wind; finally they gather in the zenith, about midday, and burst in sudden showers and terrific thunder-storms, like those of the zone of equatorial calms. The air is, at all times, nearly saturated with moisture.

As the altitude of the Sun increases, the showers become more frequent and prolonged, lasting, sometimes, the whole day; and floods of rain descend, filling the streams and inundating vast areas of country. As many as twenty-one inches of rain have been known to fall at Cayenne, in South America, in a single day.

After the Sun has passed the zenith, the rains gradually diminish in amount and frequency; and when the trade wind resumes its sway, they cease entirely.

## QUESTIONS ON THE MAP OF RAINS.

Explain the coloring of the map. What do the large figures in the margins indicate? What do the figures accompanying the names indicate? (See explanation at the bottom of the map.) What does the upper diagram on the right hand, at the bottom of the map, indicate? What is shown by the lower diagram? What do the two diagrams at the left show?

In what seasons of the year does condensation take place in the Arctic regions? Into what form are the vapors condensed? What is the average rainfall of the Arctic regions? When does condensation take place in the regions next south of the Arctic? Into what form are the vapors condensed in winter? What is the average rainfall in the northern, the central, and the southern portions of this zone?

How does the amount of rain falling annually vary from the British Isles to Siberia? (See diagram, and figures near Dublin and Barnaul.) When do the rains fall in the region of semi-periodical rains? Trace, naming the cities near it, the northern equatorial limit of the fall of snow at the sea level. Trace the limit of snow at the sea level in the southern hemisphere.

What is the average rainfall at Astrakhan, on the Caspian? At Ofen, on the Danube? At Paris? At Cherbourg, on the coast of France? Why does more rain fall on the west coast of Europe than in the interior? What two places on this coast have a larger amount of rain than any other place in western Europe? What two are next in amount? How does the rainfall vary, from east to west, in the United States, in the latitude of Cambridge?

Where are the regions of periodical rains situated? How do the seasons differ in these regions? When do rains fall in the immediate vicinity of the equator? In what portions of the globe is the average rainfall greatest? At what two places is the greatest known amount of rain? What winds bring rain at these places? Where is the largest observed amount of rain in South America?

In what portions of North America does most rain fall? What winds bring most rain there? What are the dryest regions in the southern half of North America? (See page 91, Topic I., 2.) How does the rainfall on the Sierra Nevada and Rocky mountains compare in amount with that of the plateau? Why? (See page 85, Topic II., 2.)

How does the interior of the plateau of Brazil compare in amount of rain with the eastern part? What is the cause of the absence of rain west of the Andes, in the same latitude? (See page 90, Topic I., 1.) What winds bring rain to the southern half of South America? How do the eastern and western portions of this region compare in the amount of rain? Why is this? What are the dryest parts of the Old World? How do you explain the lack of rain in northern Africa and Arabia? (See page 90, *Sub-tropical Belt.*) How do you account for the small amount of rain in the interior of eastern Asia and Iran? (See page 88, Topic III., (3).) What parts of Australia have most rain? Why is the interior dry?

Near the Equator the rainy season consists of two parts, separated by a brief period of fair weather. The first rains take place when the Sun is passing the zenith towards the adjacent tropic, and the second on his return from it. Near the tropics the two periods are blended into one.

3. EXCEPTIONAL REGIONS. (1) The *eastern coasts of the peninsula of Deccan*, in India, receive rain when the Sun is in the southern hemisphere, that is, during the northern winter.

The southwest monsoon, which blows during the summer (see page 78, Topic I., 1), and brings copious showers to the western coasts, reaches the eastern only after its passage over the Western Ghauts and the plateau of Deccan; hence it brings drought.

The northeast monsoon, blowing when the Sun is in the southern hemisphere, carries to the eastern coast abundant vapors from the Gulf of Bengal. These, condensed upon the slopes of the eastern Ghauts, give copious showers, while the western coast has its dry season.

(2) *Sub-tropical Belt.* Immediately beyond the tropics, on the margin of the trade-wind zones, between the parallels of 24° and 28°, less rain generally falls than in the neighboring latitude; and there exists, as it were, an intermediate, *dry zone.* (See Fig. 37.) Situated somewhat beyond the region of tropical summer rains, it receives but little water from that source; and it lies too near the tropics to have the benefit of the winter rains, which are brought to the latitudes beyond by the descending return-trades.

The descending branch of the return-trades re-entering the tropical regions also becomes dry because it comes into a warmer region.

The Sahara, the deserts of Arabia and Northern India, and the arid plateaus of Mexico and Lower California, all include the sub-tropical belt of the northern hemisphere; while the Desert of Atacama in South America, and of Kalahari in Africa, together with the barren wastes of Central Australia, occupy a corresponding position in the southern hemisphere.

The sub-tropical position of these regions, by diminishing their share of rain, while it increases the summer heat, deprives the soil of a covering of vegetation, and this barrenness (see page 85, Topic II., 2) intensifies both heat and drought. Thus deserts perpetuate themselves, whereas artificial irrigation has redeemed many regions naturally sterile; and by clothing the soil with vegetation, has greatly ameliorated their climate.

## III. Rains of Temperate Regions.

1. SEMI-PERIODICAL RAINS. (1) *Belt of Winter Rains.* In the *warm temperate zone*, extending from latitude 28° to about 35°, where the trades prevail in summer and variable winds in winter, the latter is the rainy season. The winter rains are occasioned by the intermingling of the cold polar current with the vapor-laden return-trades, which, in these latitudes, descend into the lower air in winter, when the sun is in the opposite hemisphere.

In other seasons, the return-trades being above and the polar winds below, the two do not intermingle sufficiently to cause any considerable condensation of vapors; and the presence of the warm air at a comparatively slight elevation, prevents condensation by ascending currents during the heat of summer. Hence little or no rain falls except in winter, and the long summers are rainless.

Thus the warm-temperate zone is characterized by a periodicity of rains scarcely less marked than that of the torrid zone, though the rain falls during the opposite season of the year.

On the Pacific coast of North America, this belt extends several degrees farther from the Equator than elsewhere. In California, as far as 40° north latitude, the rain falls almost exclusively in winter. The free sweep of the returning trade winds of the Pacific Ocean, and the mighty barrier which the Rocky Mountains oppose to the polar winds, may perhaps account for this apparent irregularity.

(2) *Belt of Equinoctial Rains.* The Sun having advanced to the Equator, the return-trades descend into the lower air, between the parallels of 35° and 42°. In these latitudes the winter rains diminish, the spring and autumnal rains show a maximum, and the summers are no longer entirely dry. They form, therefore, a transition between the belt of almost periodical winter rains, and that of the perennial rains.

In the *eastern half of the United States*, the southwesterly winds, which prevail in the summer, spread over the interior and the Atlantic plains an abundant supply of vapors from the warm waters of the Gulf. Frequent copious showers refresh the soil during the months of greatest heat, which show a maximum of rain. Thus the dry summers of the warm-temperate region disappear, and with them the periodical character of the rains, so well marked elsewhere in this belt.

2. BELT OF PERENNIAL RAINS. In the *cool-temperate* latitudes, where the warm and the cold surface winds alternate in all seasons, condensation, producing rain or snow, occurs in all parts of the year. Still, it is most abundant in summer, when the warm return-trades extend farthest north; and least in winter, especially in the interior of the continents, where the polar currents prevail to a great extent.

## IV. Rains of Polar Regions.

Within the polar regions, where southerly winds blow to a certain extent in summer, that season is marked by almost continual cloudiness and fog. The clouds are low, and fine drizzling rains are of frequent occurrence, with snow in spring and autumn. The winters, however, are dry and clear, and their long nights cloudless.

### ANALYSIS OF SECTION VIII.

- **I. Rain Zones.**
  - a. Cause and character of tropical rains.
  - b. Cause and character of rains in middle and cold zones.
- **II. Rains in Tropical Regions.**
  - 1. IN BELT OF CALMS.
    - a. Time and cause of rains.
    - b. Description of rain-storm.
  - 2. IN BELT OF TRADES.
    - a. Distinction of seasons.
    - b. Cause and character of dry season.
    - c. Character of rainy season.
      - Beginning. Height. Close.
      - Division of rainy season near equator.
  - 3. EXCEPTIONAL REGIONS.
    - a. Rains on east coast of India.
    - b. Sub-tropical rains.
      - Quantity. Cause of scarcity. Consequences.
- **III. Rains of Temperate Regions.**
  - 1. SEMI-PERIODICAL RAINS.
    - (1) BELT OF WINTER RAINS.
      - a. Location.
      - b. Cause of winter rains.
      - c. Conditions in other seasons.
      - d. Comparative periodicity.
      - e. Exceptional extent on Pacific coast.
    - (2) BELT OF EQUINOCTIAL RAINS.
      - a. Location.
      - b. Time of rainfall.
      - c. Exception in eastern half of United States.
  - 2. BELT OF PERENNIAL RAINS.
    - a. Location.
    - b. Character of winds and rains.
    - c. Maximum and Minimum.
- **IV. Rains of Polar Regions.**
  - a. Conditions in summer.
  - b. Conditions in winter.

## IX.—RAIN IN THE SOUTHERN CONTINENTS.

## I. South America.

1. INTER-TROPICAL REGION. South America, of all the continents, is the most abundantly provided with moisture. The northern and broadest part lies in the regions of daily and of periodical rains, and at the west of the Atlantic Ocean, whose

plentiful vapors are carried into it by the trade winds. The interior of the *plateau of Brazil*, however, has less copious rains, the vapors of the ocean being partially intercepted by the mountains adjacent to the coast.

In the region of the equatorial calms, copious rain falls *west of the Andes*, as well as on the eastern slope; but in the belt of southern trades no rain falls on the western slope, the vapors carried by the east winds being condensed in the passage of the latter over the mountains. From Punta Parina to 20° south latitude, the coast is bathed with vapors from the adjacent seas, which, condensed into winter fogs by the cold Peruvian current, are wafted to the lands by the southerly monsoons. Hence, though rainless, it is not entirely sterile, on account of the moisture in the air.

2. Beyond the tropics, in the regions of semi-periodical and perennial rains, the return-trades which come from the northwest, and the other westerly winds, strike the Pacific coast, but part with their vapors in crossing the Andes. *On the western slope*, Chili has only moderate winter rains; but from Valdivia to Cape Horn, clouds and rain prevail all the year round, and the average rainfall is fully as great as within the tropics.

The *eastern or main slope* is comparatively dry, especially in the higher portions near the mountains; but occasional northeasterly winds, bringing showers, and thunder-storms from the south during the summer, redeem this part of the continent from complete aridity,

Paraguay, southern Brazil, and the states west of the La Plata, have the winter and equinoctial rains of these latitudes, coming from the north and northeast; but the Pampas of Buenos Ayres are liable to long and frequent droughts, and the dryness of the Patagonian plains is in great contrast with the excess of moisture on the opposite side of the Andes.

### II. Africa.

1. Central Region. Africa has, like South America, copious rains in the zone of calms, and in the zones of periodical rains, as far as 16° north latitude and 20° south. No high and continuous mountain ranges shut out the moisture brought by the monsoons, both from the Indian and the Atlantic Ocean (see *Map of Winds*); though the marginal swells partially intercept the vapors, giving to the coasts more abundant rains than to the interior.

2. Northern Africa. With the exception of the Mediterranean shores, a narrow belt along the Atlantic coast, and some groups of mountains in the interior, North Africa, beyond latitude 16°, is almost absolutely rainless. These exceptional regions receive the winter and spring rains of the extra-tropical zone.

The *rainless region* forms the Sahara, the largest desert upon the globe. Its aridity is occasioned by the position of a great portion of its area in the sub-tropical zone; its situation at the southwest of the great continent of Asia, which causes the prevailing northeasterly winds of its latitude to come from arid lands; the elevation of the plateaus of Arabia aud Abyssinia, which exclude from it the winds from the northern part of the Indian Ocean; and the nature of its surface, which is such as to be most unfavorable to condensation. (See page 85, Topic II., 2.)

3. Southern Africa. A portion of the continent beyond the parallel of 20° south latitude, is also in the sub-tropical zone, and has its desert, that of Kalahari, under the Tropic of Capricorn; but its less extent, and its exposure to the winds from the surrounding seas, redeem it from the complete drought belonging to the Sahara. The two arid regions, embracing so large a portion of its area, give Africa its especial character, rendering it the hottest of all the continents, and the dryest in the tropical regions.

### III. Australia.

Australia, regarded as a whole, is somewhat scantily supplied with rain; but, as in southern Africa, the small area of the continent, its position in the midst of the sea, and the absence of barriers excluding the sea winds, all tend to diminish the dryness of its sub-tropical belt. The northern portion receives the periodical summer rains of inter-tropical regions, and the southern the semi-periodical, or spring and winter rains.

#### ANALYSIS OF SECTION IX.

**I. South America.**
  1. Inter-tropical Region.
    a. Comparative abundance of moisture.
    b. Rains west of the Andes in the belt of calms.
      In the trade belt.
  2. Rains Beyond the Tropic.
    a. On western slope.
    b. On eastern slope.
**II. Africa.**
  1. Central Region.
  2. Northern Africa.
    a. General character in regard to moisture.
    b. Rainless region.
  3. Rains in South Africa. General character of Africa.
**III. Australia.**
    a. General character.
    b. Rain in the different portions.

## X.—RAINFALL OF THE NORTHERN CONTINENTS.

### I. North America.

1. General Character. *North America* has, in the eastern half, a greater amount of rain than either of the other northern continents, in similar latitudes. Though the primary highlands, which lie in the western part, across the track of the return-trades, oppose the entrance of the moisture from the Pacific into the interior; yet the great sub-tropical basin of the Gulf of Mexico sends up into the air its wealth of vapors, to replace those lost by the winds in crossing the high mountain chains.

Hence the eastern portions,—the great basins of the Mississippi and the St. Lawrence, and the Appalachian region,—which without this source of moisture would be doomed to drought and barrenness, are the most copiously watered and the most productive portions of the continent.

2. Arid Regions. The plateau of Mexico and the peninsula of California—situated in the sub-tropical zone;—the interior plateaus east of the Sierra Nevada; and a narrow belt of the high plains east of the Rocky Mountains, south of 42° north latitude, are the only exceptions to the abundance of moisture which characterizes this most favored continent. Even these regions are not entirely rainless, but receive, to some extent, the winter, equinoctial, or summer rains belonging to their several latitudes.

### II. Europe.

1. General Character. Europe is well watered throughout, with the exception of a narrow region of steppes adjacent to the Caspian Sea. But, excepting a few points immediately on the Atlantic and Mediterranean coasts, the average annual rainfall in Europe is several inches less than in North America.

2. Exceptional Regions. The *places* which receive most abundant rains are Coimbra, at the foot of the mountains, on

the western coast of Portugal; Bergen, on the Scandinavian coast; Bayonne, at the head of the Bay of Biscay; Tolmezzo, at the head of the Adriatic Sea; and Seathwaite, on the west coast of England, in the Cumberland Mountains.

Peculiarities of relief *explain the exceptional rainfall* of these regions. At Tolmezzo, for example, an arc of high mountains encompasses the head of the Adriatic, on the side opposite the wind; and condenses, upon a small area, all the vapors brought within its circumference. At Seathwaite the isolated mountain group, rising into the region of clouds, performs the same work. Similar conditions exist at each of the other places named.

### III. Asia.

1. General Character. Asia, the greatest and the coldest of the land masses, with the loftiest mountains and the largest plateaus, has, regarded as a whole, less rain than any other of the northern continents. The main slope, which includes the whole continent with the exception of the southern peninsulas, is directed towards the north; and is open to the dry polar winds, while the moist return-trades are shut out from it.

In the *zone of perennial rains* less water falls than in the corresponding zone of Europe. In the zone of *semi-periodical rains*, where the surface consists mainly of mountain-girdled plateaus or sandy marine plains, little rain falls except on the mountains. The regions of greatest rainfall, in the latter zone, are Asia Minor, the Caucasus, and the Caspian shores, in western Asia; the Thian Shan, and Pamir, in the centre; and middle and north China, in the east.

The plateau of Arabia, the adjacent table-lands of Syria and Iran, and the vast plateau of Mongolia, have, in general, but scanty rains. They, with the Sahara, form a great central belt of deserts, extending from the Atlantic, in Africa, nearly to the Pacific shores in Asia.

2. Periodical Rains. The southern part of China, the peninsulas of India and Indo-China, the southeast coast of Arabia, and the Indian Archipelago, lie in the *zone of periodical rains*. Here the rains, which are copious, accompany the monsoons; and the opposite coasts of the great Indian peninsulas receive rain at opposite seasons. Even on these favored shores, however, except at a few points where local peculiarities of relief give an amount of rain entirely unparalleled, the rainfall is less than on the coasts and islands of tropical America.

The interior of the Deccan, a plateau surrounded with mountains, receives little rain. On the Arabian shores, though there is an abundance of rain, yet as it falls in a single season, usually with great violence, and flows away almost immediately, it benefits the soil but little. Only the valleys are permanently watered.

Cherraponjee, near the head of the Bay of Bengal, in the Cossyah Mountains, which rise isolated from the low plains of India, receives the greatest fall of rain on record; viz., 610 inches. At Mahabuleshwur, in the Western Ghauts of India, 4,500 feet above the sea level, 254 inches of rain have been recorded.

### ANALYSIS OF SECTION X.

**I. North America.**
  1. General Character.
  2. Arid Regions.

**II. Europe.**
  1. General Character.
  2. Regions of Greatest Rainfall.

**III. Asia.**
  1. General Character.
    a. Cause of scarcity of rain.
    b. Moisture in zone of perennial rains.
    c. Moisture in zone of semi-periodical rains. Rainless regions.
  2. Zone of Periodical Rains.
    a. Regions included.
    b. Time of rain. Amount.
    c. Rain in the Deccan.
    d. Regions of excessive rain.

## XI. — SNOW.

### I. Formation.

Vapor condensed in air having a temperature below 32° Fahr. freezes, or passes to a crystalline form, producing snow. Snowflakes occur in a great variety of forms, which usually present the outline of either a regular hexagon or a six-pointed star.

Their size depends upon the temperature and the relative humidity of the air through which they fall; for, like raindrops, they increase by successive additions from the vapors with which they come in contact in descending. Thus in mild weather they are much larger than in very cold weather.

When the lower air is warm enough partially to melt the crystals, they form minute balls. When raindrops, formed in the upper air, fall through a cold current, they are often frozen, producing sleet instead of snow.

### II. Horizontal Distribution.

In high and middle latitudes, the ground is covered with snow each winter; but *within the tropical regions* no snow falls at or near the level of the sea, for the temperature of the lower atmosphere is always sufficient to melt the crystals, even if they are formed in the upper air.

In the northern hemisphere the *limit of the fall of snow* at the sea level is an irregular line lying mainly between 25° and 40° north latitude; in the southern it is somewhat regular, lying about latitude 43° in the oceans, and from 32° to 38° in the continents.

In general, this line is nearest to the equator in the regions most exposed, in winter, to polar winds; as on the eastern coast of Asia and North America.

The *period of continuance of snow* increases with the distance from the limit of snow fall. Rome, for example, has an average of one and one-half snowy days in the year; Paris has twelve, Copenhagen thirty, and St. Petersburg one hundred and seventy-one.

The *quantity of snow falling* annually is greatest in cool-temperate latitudes, since the amount of vapor in the air within those regions is greater than in the polar regions.

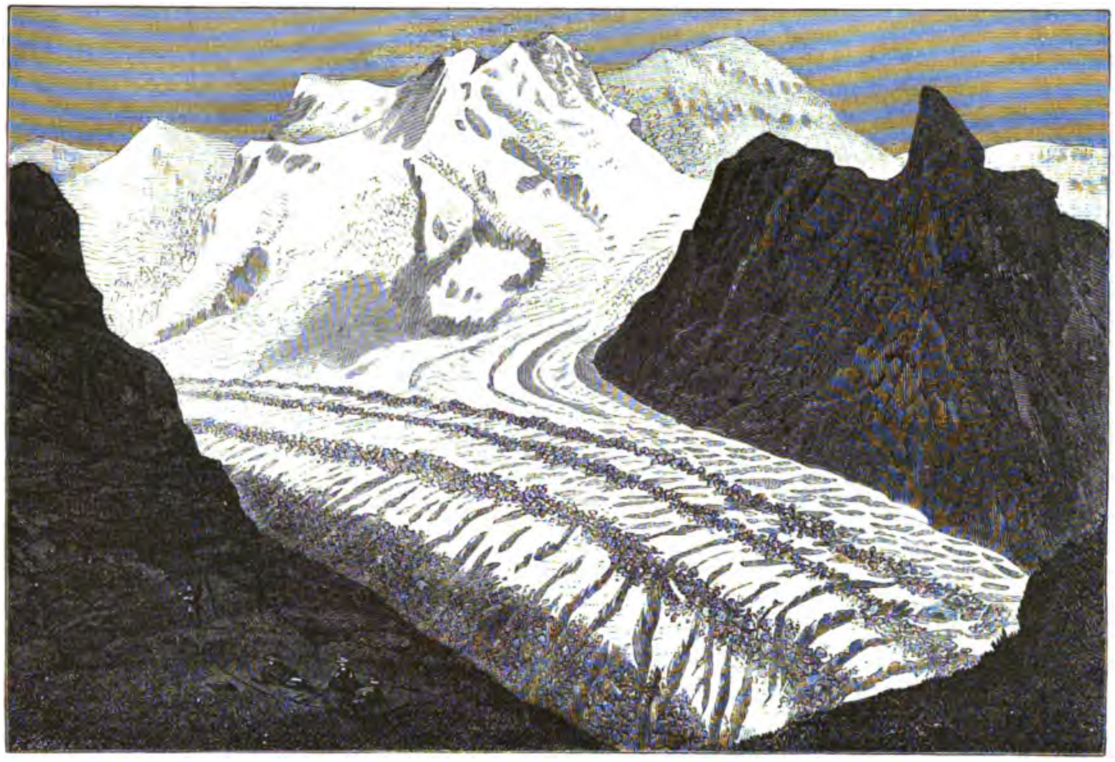
As the warmth of the air diminishes upward, a temperature permitting the fall of snow may always be found upon high mountains, even under the equator.

At the summit of the Andes, for example, the moisture which is condensed during the rainy season falls in the form of snow, while the slopes, and the plains at their foot, are drenched with rain.

### III. Permanent Snow.

1. Where Found. Though the winter snows upon the plains, and the slopes of mountains of medium height, disappear during the warm season; yet, in all latitudes, the tops of high mountains are covered with a layer of permanent snow, which the summer heat of these great altitudes is not sufficient to melt.

The lower limit of perpetual snow, called the *snow line*, is found, within the tropics, about three miles above the level of the sea. In temperate latitudes it occurs at the height of a little less than two miles; and at the northern limit of the continents, it is about half a mile above the level of the sea, or, perhaps, even less than this.



GLACIER OF ZERMATT, MONTE ROSA, CENTRAL ALPS.

On the Arctic islands, vast fields of snow remain permanently, at a few hundred feet above the sea level.

The winter snows, falling into the icy waters of the polar oceans, are but partially dissolved; and, remaining upon the freezing surface, they help to form those vast *ice floes* which encumber the polar seas at all times.

2. Height of the Snow Line. The following table gives the observed height of the snow line in the different latitudes: —

| Lat. N. | New World. | Eng. ft. | Lat. N. | Old World. | Eng. ft. |
|---|---|---|---|---|---|
| 75° | North Greenland . . . . | 2,300 | 75° | Baer Island . . . . . . | 600 |
| 54° | Unalashka . . . . . . | 3,500 | 71° | Mageroe, Cape North . . | 2,300 |
| 48° | Mt. Baker, Oregon, about . | 8,000 | 67° | Sulitelma, Lapland . . . | 3,800 |
| 43° | Rocky Mountains . . . . | 12,500 | 61° | Scandinavian Alps . . . | 5,300 |
| 39° | Rocky Mountains . . . . | 14,500 | 50° | Altai Mountains . . . . | 7,000 |
| 38° | Sierra Nevada . . . . . | 11,000 | 46° | Alps, north side . . . . | 8,800 |
| 19° | Popocatepetl, Mexico . . | 14,900 | 46° | Alps, south side . . . . | 9,200 |
| 5° | Tolima, Columbia . . . . | 15,300 | 43° | Caucasus . . . . . . . | 11,000 |
| Lat. S. 1° | Andes of Ecuador . . . . | 15,800 | 35° | Hindoo Koosh . . . . . | 13,000 |
| 17° | Andes of Bolivia, west side, | 18,500 | 31° | Himalaya, south side . . | 16,200 |
| 17° | Andes of Bolivia, east side, | 15,700 | 31° | Himalaya, north side . . . | 17,400 |
| 33° | Andes of central Chili . . | 14,700 | 12° | Abyssinian Mountains . . | 14,000 |
| 42° | Andes of Patagonia . . . | 6,000 | Lat. S. 3° | Kilima Njaro . . . . . | 16,000 |
| 54° | Andes of Straits of Magellan | 3,700 | 44° | New Zealand Alps . . . | 7,500 |

The snow line was formerly supposed to be a curve coinciding with the vertical isothermal of 32° Fahr. — the freezing point — and rising regularly, with the average temperature, from the polar regions to the equator. Neither supposition has proved to be entirely correct. The mean temperature of the air at the snow line is, according to observation, several degrees below the freezing point; and the table shows that this line is subject to great irregularities of elevation, also that its extreme altitude is not at the equator, but in the vicinity of the tropics.

3. Irregularities in Elevation. The elevation of the snow line depends upon two conditions: the quantity of snow which falls, and the amount of heat there is to melt it. Neither, alone, but the relation between the two, determines the limit of perpetual snow. Thus in the sub-tropical zones, which have less snow, with no less summer heat, the snow line is higher than at the equator.

In similar latitudes the coast regions, exposed to moist winds, have a lower snow line than the interior of the continents, with their scanty snows, dry atmosphere, and hot summers. The peaks of the Sierra Nevada bear perpetual snow, 3,500 feet lower than the Rocky Mountains, in the same latitude. The south slope of the Himalayas, which condenses the abundant vapors brought by the warm monsoons, has a snow limit, on an average, 2,000 feet lower than the north slope, on the dry and sunny plateau of Thibet.

In the Alps, which are well watered on both sides, the limit of snow is somewhat higher on the southern slope; for here the exposure to the warm summer winds more than compensates for the slight excess in the amount of snow which falls on the south side.

In passing from the dry climate of central Chili to the rainy region farther south, the snow line descends from 14,700 feet to 6,000. A vast amount of snow in the latter region, and a wet and cloudy summer, account for the change. In the Rocky Mountains, in the latitude corresponding to that of the Patagonian Andes, the snow line has an altitude of 12,500 feet.

### ANALYSIS OF SECTION XI.

**I. Formation.**

**II. Horizontal Distribution.**
- a. Snow in tropical regions.
- b. Limit of snow at sea level.
  - In northern hemisphere.
  - In southern hemisphere.
- c. Period of continuance of snow.
- d. Amount of snow falling. Snow on elevations.

**III. Permanent Snow.**
- 1. Where Found.
  - a. In tropics.
  - b. In temperate and polar regions.
- 2. Snow Line.
  - a. Table of altitudes.
  - b. Former supposition regarding snow lines.
- 3. Explanation of Irregularities.
  - a. Altitude depends on what.
  - b. Region of highest snow line.
  - c. Snow line in coast regions.
  - d. Snow line on opposite sides of Himalayas and Alps.
  - e. Snow line in southern Andes.

## XII. — GLACIERS.

### I. Nature and Aspect.

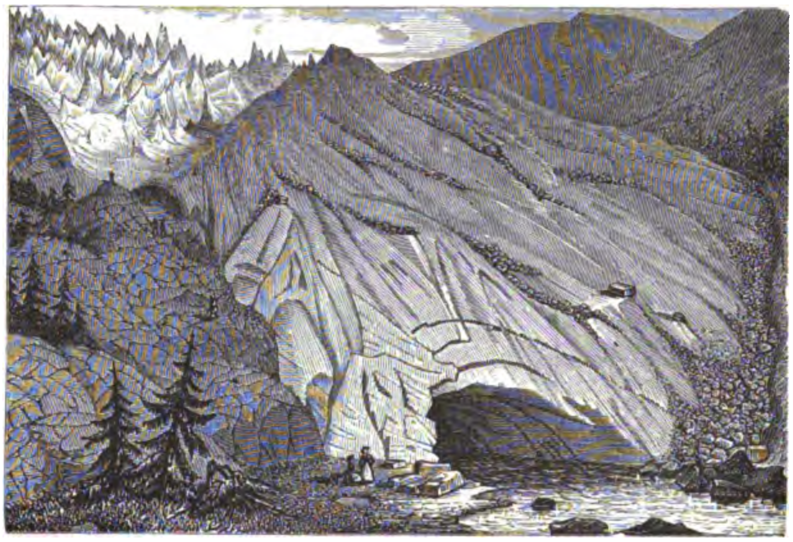
Glaciers (from the French *glace*, ice) are vast streams of ice which descend from the lower edge of the perpetual snows, like long icicles from a snow-covered roof. They follow the windings of the Alpine valleys, and terminate abruptly in a massive wall of ice, from beneath which the waters of the melting glacier escape, through a large icy vault. (See illustrations on this and the following page.)

The *great glaciers of the Alps* extend downwards from 3,000 to 6,000 feet below the snow line, and are from ten to fifteen miles in length. They are thus a beautiful provision for discharging, from the regions of perpetual frost, the excess of snow, in order that it may melt in the more genial atmosphere below. All the main Alpine streams — the Rhine, the Rhône, the Aar, and others — have their origin in the glaciers; and both these rivers and the lakes through which they pass have high water in summer, when the melting of the ice and snow is most rapid.

When the slope is gentle, the *surface* of the glacier is comparatively smooth. When it becomes precipitous, the mass of ice breaks up, deep crevices open, and the glacier assumes the form of a gigantic frozen cataract; but beyond the precipice it becomes even again.

The illustration on page 93 shows the smooth part of the great glacier of Monte Rosa, in the valley of Zermatt, the moraines upon its surface, and the formation of crevices at the head of a rapid slope. Below is shown the shattered mass, resolved into sharp ice-needles, as they are called; also the terminal wall of the glacier, with its vault, and the stream issuing from beneath.

*Glaciers of the first order* fill the main valleys, and, like the great river systems, are usually composed of several tributaries, or glaciers of the second order, which unite in one channel. But the ice does not blend, like the water, in confluent streams. The several glaciers, though strongly compressed, are united only by their margins; and each preserves its individual structure, often to the end of its journey.



TERMINATION OF THE GLACIER OF ZERMATT.

## II. Formation.

The first *condition for the formation* of a glacier, is an accumulation of snow which can be but partially melted by the heat of summer. Such accumulations are favored by the structure of the great Alpine valleys, most of which expand, within the region of perpetual snow, into vast amphitheatres; each forming an immense common reservoir, into which the surrounding peaks all send down their loads of snow.

The *process of gradual formation* is indicated by the variations in the substance of the glacier in different parts of its course. In the cold, frosty, upper regions, the snow, composed of small crystals as yet unmelted, is dry and powdery. Lower down, a partial melting and agglomeration of the crystals, converts them into coarse, white grains, forming the *névé* (from the French *neige*, snow), which is always found somewhat below the snow line.

The melting process continuing, the névé is gradually soaked by the percolating waters; and, under the influence of freezing nights and constant pressure, it at length becomes a consolidated mass, like a frozen snow-bank in the spring. This is the beginning of the glacier proper.

Still lower, regular laminæ of transparent ice appear in the midst of the frozen snow; and gradually the alternate melting and refreezing, under high pressure, converts the whole into the blue transparent ice which forms the lower portion of the glacier. The surface alone, owing to constant disintegration, appears whitish.

*Glacier ice*, however, never loses the traces of its origin, but a blow of the hammer will cause it to crumble to pieces and reveal its granular structure. This explains how the water from the melting surface can pervade the entire mass, and render its particles movable, thus facilitating its gradual descent.

## III. Motion.

Glaciers descend constantly along the valleys they occupy, though with an irregular velocity. As in streams, a more rapid slope, or a greater mass, accelerates, and a more gentle slope, or a smaller mass, retards the motion.

The *rate*, varying in different glaciers, is always greater in summer than in winter; and is greatest when the melting is most rapid. In glaciers of the first order, the ordinary progress is from ten to twenty inches a day; but sometimes, as observed in the Mer de Glace, on Mont Blanc, it reaches two feet or more.

The bottom and sides are retarded by friction against the rocky walls of the valley, while the top and centre, moving more freely, are more and more in advance. Hence the lower end of the glacier, when free to expand — as that of the Rhône, in Switzerland — terminates in a convex semicircle.

The *termination* of a glacier, notwithstanding the constant descent, occupies from year to year about the same average position; for the melting in summer is generally sufficient, not only to dissolve the extremity as rapidly as it advances, but also to remove what has been gained during the previous winter.

Heavy snows, however, followed by a cloudy and cool summer, which diminishes the amount of melting, may permit the glacier to extend beyond its usual limit; while a dry winter, or an unusually hot and clear summer, may reduce both the length and thickness below the average. In the latter case, the waste during the summer exceeds the gain during the winter.

## IV. Transportation of Rocks.

Glaciers, like mountain torrents, transport fragments of rock of all sizes, which have gradually crumbled from the uncovered peaks and slopes above them. But owing to the slow and steady motion, the arrangement of this *débris* is entirely different from that of materials transported by water.

1. Moraines. On the surface of all great glaciers (see page 93) are narrow and well defined bands of rocks and rubbish, called *moraines*. They are both *lateral*, lying along the sides, and *medial*, in the centre of the glacier. The latter either come from rocks in the upper part of the valley, or are formed by the united lateral moraines of confluent glaciers.

As the ice melts, at the end of the glacier, the rocks fall to the ground; and, with pebbles and mud from beneath it, form a *terminal moraine*. This is sometimes of great height, and is usually in the form of a semicircular wall across the valley.

A surface moraine, whether lateral or medial, is composed, from beginning to end, of the same kinds of rock, often of one or two kinds only; and two moraines lying side by side may be formed of rocks of an entirely different nature; for each brings the *débris* from a different part of the valley, sometimes from a single crumbling peak. These broken fragments, falling one after the other on the same spot, are, by the steady advance of the glacier, successively carried down along the same line, to the terminal moraine, which receives them all.

2. Action of Glaciers on their Beds. The constant friction of these vast masses of ice on the surface of their rocky beds, rounds off the projections over which they pass, and smooths and polishes even hard granite and marble. The fine mud, composed of the hardest particles of these crystalline rocks, adhering to the ice, is the polishing powder. Coarser grains cut, on the polished surface, systems of fine parallel scratches; and larger pebbles form long parallel furrows, all indicating the direction of the moving ice.

Old moraines, polished and grooved rocks, and other evidences of glacier action, so different from that of water, show that, in a time long past, vast and thick glaciers existed in New England and other parts of North America, and in Europe where no permanent snows are now found.

### V. Geographical Distribution.

The mountain systems in the middle latitudes, with abundant snows and alternate warm and cold seasons, are most favorable to the formation of glaciers. The best known, and probably the most remarkable *glacier region* is that of the high Alps, in the heart of which are Mont Blanc, Monte Rosa, and the Bernese Alps.

The Pyrenees have glaciers of the second order only. Late explorers have found large glaciers in the Caucasus and in the Himalayas, the last being of the grandest proportions. In the Scandinavian Alps are many which descend, in the deep western fiords, nearly to the sea level.

In the New World glaciers are less frequent. They are entirely wanting in the tropical Andes, the constancy of temperature throughout the year, as well as the structure of the snow-covered peaks, being unfavorable to their formation. In the snowy Patagonian Andes, however, they are numerous and well defined.

In the high Sierra Nevada, polished and grooved rocks, and old moraines, showing the former presence of great glaciers, are found down to 4,000 feet above the sea level; but no glaciers have been discovered. Farther north, on Shasta Peak and Mt. Rainier, genuine glaciers of the second order have been noticed.

By far the *most extensive glaciers*, however, are found on the snow-covered islands of the polar oceans. The gigantic Humboldt glacier, discovered by Dr. Kane on the shores of Smith Sound, is sixty miles in breadth, rises three hundred feet above the water, and extends an unknown distance into the interior. Similar, though perhaps less extensive, glaciers occupy nearly all the valleys of Greenland, Spitzbergen, and other Arctic and also Antarctic islands.

Vast masses of ice, broken from the ends of these glaciers, form the enormous icebergs (mountains of ice) which are so numerous in the polar seas, and are transported by the currents even to middle latitudes. (See *Limit of drifting ice*, in map, pages 28, 29.)

THE AURORA BOREALIS.

ANALYSIS OF SECTION XII.

**I. Nature and Aspect.**
  a. Character, extent, and termination.
  b. Surface.
  c. Situation and composition of great glaciers.
**II. Formation.**
  a. Condition of formation.
  b. Process, how indicated. Appearance of mountain snows.
    Structure of different parts of glacier.
    Peculiarity of glacier ice.
**III. Motion.**
  a. Continuity and irregularity of progress.
  b. Rate in different seasons. Average rate. Bottom and sides.
  c. Termination.
**IV. Transportation of Rocks.**
  1. MORAINES OF WHAT FORMED.
    a. Surface moraines how situated.
    b. Terminal moraines.
  2. ACTION OF GLACIERS ON THEIR BEDS.
**V. Geographical Distribution.**
  a. Most noted glacier region.
  b. Other glacier regions of Old World.
  c. Glaciers in New World.
  d. Most extensive glaciers. Icebergs.

## XII.—OPTICAL AND LUMINOUS PHENOMENA.

### I. Introduction.

A number of striking phenomena, both optical and luminous, arise from the *physical properties* of the atmosphere. The explanation of them belongs, however, to the subject of natural philosophy rather than physical geography, for the latter investigates the atmosphere only as furnishing the conditions of life upon the globe. Hence, they will be touched upon here only in a very general way.

### II. Optical Phenomena.

1. RAINBOWS are arches of prismatic colors, formed by the reflection of rays of light from within drops of water. The rays, which are refracted in entering the drops, are reflected from their posterior surfaces, and again refracted as they re-enter the air, the colors being separated by their unequal refrangibility.

2. HALOS and CORONAS are circles of prismatic colors which, in certain states of the atmosphere, surround the Sun and the Moon.

*Halos* are supposed to be occasioned by the presence, in the atmosphere, of small ice crystals which act as minute prisms, decomposing and refracting the light which passes through them. Their size is fixed, as they are seen only under a visual angle of either 22° or 46°.

*Coronas* are seen when a light mist is floating in the air, and are supposed to be formed by reflection from the external surface of the globules of vapor.

3. COLORS OF THE SKY AND CLOUDS. The azure tint of the *cloudless sky* is due to the decomposition and refraction of light, as it passes through layers of air successively increasing in density. The blue and violet, being more refrangible than other colors of the solar spectrum, are diffused through the atmosphere; and being reflected from its particles, they impart to it their own color.

The *clouds* floating in the atmosphere absorb the more refrangible rays, and reflect the less. At sunrise and sunset, when the light traverses the greatest depth of atmosphere, all the colors are absorbed except the red and the yellow; and these, being reflected from the particles of vapor, produce the brilliant coloring of the evening and morning clouds.

4. The MIRAGE is an optical phenomenon in which images of distant objects are seen, reflected beneath, or suspended in the heavens above. Occasionally, also, objects are seen double, being repeated laterally instead of vertically.

The mirage is caused by the refraction and reflection of light as it passes from denser to rarer strata of air. It is most frequent in arid plains, where the soil, exposed to the burning rays of the sun, becomes intensely heated, and, in consequence, the strata of air near the ground are less dense than those above.

In this case rays of light passing from any distant object, as a tree, to the ground, are refracted more and more towards the horizontal, until finally they are reflected from a horizontal layer of the heated air, and reach the eye from beneath. Then an image of the object is seen as if mirrored in the tranquil waters of a lake.

### III. Luminous Phenomena.

1. LIGHTNING is the dazzling light produced by an electrical discharge passing between clouds which are oppositely electrified, or between the clouds and the Earth. Lightning *flashes* have been distinguished as zigzag or chain lightning, sheet, and globular lightning.

The first has the aspect of a sharply defined chain of fire, and moves at the rate of 250,000 miles per second. Its zigzag course is attributed to the resistance of the air, condensed in the passage of the electrical discharge, which is sufficient to turn it aside frequently in the direction of less resistance.

Sheet lightning includes the expanded flashes which occur during a storm, and the heat lightning, seen on summer evenings, when no clouds are visible, which is supposed to be the reflection of a storm taking place below the horizon.

Globular lightning is seen on rare occasions, when the electrical discharge takes the form of a ball of fire, and descending with less rapidity, is visible for several seconds. In certain conditions of the atmosphere, globes or spires of electrical light, called *St. Elmo's fire*, are seen tipping the extremities of bodies in contact with the earth, like church spires, or masts of ships.

All the conditions which give rise to electrical excitement in the atmosphere are much more intense in warm than in cold latitudes; hence the *thunder-storms of the tropical regions* greatly exceed, both in frequency and in violence, those of temperate and cold climates.

2. The AURORA BOREALIS, or northern light, is a phenomenon frequently observed in the northern heavens. It occurs in many forms, but the most com-

mon is that of a luminous arch (see page 95) whose summit is in the magnetic meridian of the place of observation, and from which vivid flashes of light dart towards the zenith. A like phenomenon in the southern heavens is denominated the Aurora Australis. Auroras are *most frequent* and brilliant in the polar regions, and diminish in intensity towards the equator.

The constant relation existing between the arch and the magnetic meridian, together with the oscillation of the magnetic needle during the auroral display, suggests the idea that this phenomenon is caused by electrical currents in the higher atmosphere. But no explanation thus far proposed, can be accepted as entirely satisfactory.

## REVIEW OF PART IV.

**I.**

(69.) How is the weight of the atmosphere measured? How does its density vary? At what distance from the sea level is the weight of the atmosphere reduced by one-half?

(70.) What is the height of the atmosphere? How is the atmosphere related to organic life?

Define climate. What is its fundamental phenomenon? What is astronomical climate?

What is physical climate, and on what does it depend?

**II.**

What is the general law of the distribution of heat upon the globe?

What are the causes of the diminution of heat from the equator towards the poles?

Explain the change of seasons, and the variation in the length of day and night.

(71.) What effect has the variation in the length of the day upon the temperature of different seasons? What is the law of variation in the inequality of day and night?

What is the result of this variation? What are the seasons in the different zones?

When is the heat greatest in middle and polar latitudes? Why?

**III.**

(72.) What are isothermal lines, and what is their object?

What is the character of the general deviations from astronomical climates, and how are they caused? What is the nature and extent of the deviations due to altitude?

How does the temperature of plateaus compare with that on mountain peaks of the same altitude? Why? How do winds and marine currents modify the astronomical climates?

On which hemisphere are the astronomical climates most modified?

Where do the extreme deviations from astronomical climates occur? Give examples?

Explain the manner in which these deviations are produced.

(73.) How do the eastern and western coasts of the southern continents compare? Why?

How do the zones of physical climate differ from the astronomical zones? State the limits of the several physical zones, with their comparative extent in the different continents.

Describe absorption and radiation of heat by water; by land. What is the result upon climates? What is the character of the oceanic climate? Of the continental climate? Of the coast, or maritime, climate?

To what extent can the influence of the continents and the oceans on climate be traced?

**IV.**

(76.) What are the conditions of the equilibrium of the atmosphere? What is the result of a disturbance of the equilibrium? What are winds, and how are they classified and named?

Describe and name the general currents of the atmosphere. How are they caused?

What are the directions of the polar and return currents, and what gives these directions?

(77.) What local causes affect the general directions of these currents?

What zones result from the general laws of atmospheric circulation?

What are the trade winds? Where do they blow with regularity, and why only there?

Where do they commence, and what is their rate of motion?

Define and explain the equatorial zone of calms. What other belts of calms are known?

How does the position of the belts of trades and calms vary in different parts of the year?

What general land winds are noticed in the zones of trades?

**V.**

(78.) What are monsoons? Explain the monsoons of the Indian ocean.

Explain the cause of the diurnal land and sea breezes; the diurnal mountain breezes.

What periodical winds are observed in the neighborhood of great deserts, and what is their direction? (79.) Describe these deserts, winds, and their effects.

What are the etesian winds? The northers? What are the prevailing currents in the zone of variable winds? What is the effect of their differing temperatures and directions?

In what order do the normal currents displace each other in each hemisphere?

How is the effect of the transition of the winds manifested?

What are the starting-points of the polar winds, and why in these regions?

What is the direction of the coldest winds in eastern North America, and why?

What change takes place in the polar winds as the sun advances northward, and why?

Describe the range and the effects of the polar currents; of the return trades.

**VI.**

(82.) What are cyclones? What is the direction of their motions, in each hemisphere?

Where do the West India hurricanes originate, and what is their cause?

(83.) Describe the course necessary to escape from a hurricane, in each hemisphere?

What is the extent of the cyclones, and when are they most frequent?

How can the northeasterly storms of the Atlantic seaboard be explained?

Describe the successive changes of the wind, in different portions of the area of those storms.

What are tornadoes? Waterspouts? (84.) What is the cause of the tornadoes?

**VII.**

Upon what does the capacity of the air for receiving vapor depend? What is saturation?

How can the relative and the absolute humidity of the air be ascertained?

How are clouds classified, and what are the principal forms? Describe each.

(85.) What is the general cause of condensation and rain? Examples.

What is the effect of mountain chains on the condensation of vapors? Examples?

What is the comparative amount of rain on plateaus, and why? What influence has the nature of the soil on the condensation of the vapor in the air? Advantage of forests?

(88.) How does the average annual rainfall vary in different latitudes? Why?

How does the amount of cloudiness, and the number of rainy days in the year, vary? Why?

How do the coasts compare with the interior of the continents in moisture? Why?

How does the New World compare with the Old in its average rainfall? Why?

What is the average in each, in both temperate and tropical latitudes?

**VIII.**

(89.) What peculiarity in regard to rains characterizes the tropical regions, and why?

How are the temperate and cold regions characterized, and why?

Describe the rains in the zone of calms. When do the rains occur in the zone of trades, and why? Describe the dry season. The rainy season.

What is the time of rain on the opposite coasts of the Deccan, and why?

(90.) Describe the sub-tropical belt. What is the time and cause of rain in the warm temperate zone? In the temperate proper? In the polar zone?

**IX.**

What is the relative amount of rain in South America?

Describe the distribution of moisture in the intertropical region. Beyond the tropics.

Why are the Peruvian Andes dry on the western slope, and those of southern Chili and Patagonia on the eastern? Why are the Andes of northern Chili dry on both slopes, and those of Columbia and Ecuador wet on both?

What are the conditions of central Africa in regard to rain, and why?

Describe the distribution of rain in northern Africa. To what is its aridity due?

What is the character of southern Africa? Of the continent as a whole?

What is the relative amount of rain in Australia, and the time of rain in different portions?

**X.**

Describe the distribution of moisture in North America.

What is the cause of the dryness of the western plateaus? How would the distribution of moisture in this continent be affected if the Gulf of Mexico should become dry?

What is the distribution and comparative amount of moisture in Europe?

(92.) How do you explain the exceptional rainfall at Tolmezzo? At Seathwaite?

What is the comparative amount of rain in Asia, and why?

Describe the distribution of moisture in the zone of semi-periodical rains. How do you account for the extreme inequality of rainfall in the different parts of this region?

Describe the distribution of moisture in the region of periodical rains. Where do you find the greatest amount of rain on record? How can you explain this excessive rainfall?

**XI.**

In what regions of the earth does snow fall at the sea level? Why only there?

How does the period of continuance of snow vary in different latitudes? The quantity which falls? What is the average altitude of the snow line in the different zones? (93.) Upon what does its altitude, in any region, depend?

Where does the snow line have its greatest altitude, and why? How does its altitude in the coast regions compare with that in the interior of the continents, and why?

**XII.**

What are glaciers? (94.) What is the extent of the great glaciers of the Alps?

What is the first condition of the formation of a glacier? Describe the process of formation.

Describe the motion of the glaciers. What prevents the descending glacier from encroaching on the lower lands? What are moraines, and how are they formed?

What is the effect of glaciers upon the rocks in their bed?

(95.) What regions are most favorable to the formation of glaciers? Why? Where are glaciers most extensive? Why are glaciers absent from the tropical Andes?

**XIII.**

Upon what do the luminous and optical phenomena of the atmosphere depend?

How are rainbows formed? What are halos and coronas, and how are they formed?

What gives the cloudless sky its blue tint? What causes the brilliant colors of the clouds?

What is the mirage, and how is it caused? Where is it most frequent, and why?

What is lightning? What is the velocity of zigzag lightning?

How are the auroras supposed to be caused? Where are they frequent and brilliant?

# PART V.

# LIFE UPON THE EARTH.

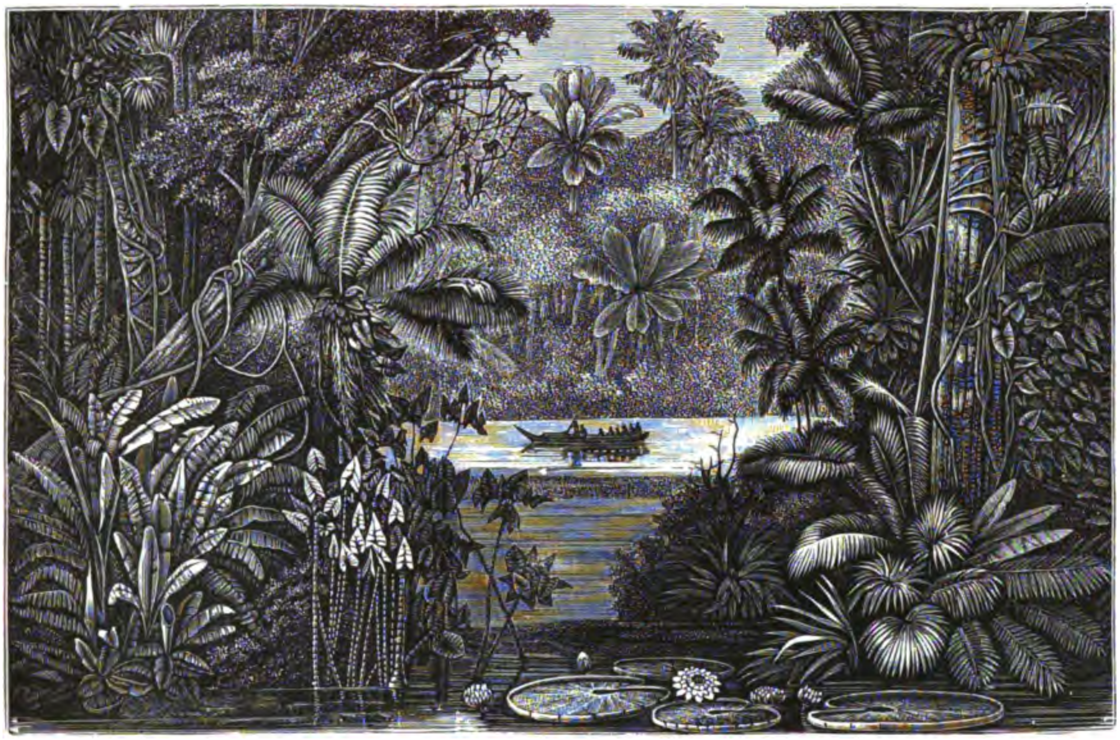
## I.—LIFE IN NATURE.

### I.—INTRODUCTION.

1. The System of Life in nature is represented by the vegetable and the animal world; while man is its representative in the higher, spiritual sphere of the mind.

2. Plants and Animals, unlike minerals, grow from germs, and develop into individuals, with definite forms and organs. After a limited existence, they die, their species being perpetuated by seed or offspring. The *functions* of plants and animals in nature are, however, entirely unlike.

The *plant*, alone, transforms inorganic into organic matter, and thus prepares food for the animal. In its quiet steady growth, it gathers a store of force which the animal expends in action. Thus the distribution of vegetation regulates that of animal life.



A FOREST ON THE ORINOCO.

The *animal*, being called upon to move and act, is endowed with sensation and will; but neither is required in the passive, motionless life of the plant.

*Vegetation* not only forms the indispensable link between inorganic nature and animal life; but it clothes the surface of the land with that rich mantle of verdure and flowers which is its greatest ornament. More than any other element in the landscape it is indicative of the climate, and gives to every part of the globe its peculiar and characteristic aspect. (*Teacher*, see *note*, page 122.)

### II.—VEGETATION IN DIFFERENT LATITUDES.

### I. Zones of Vegetation.

Sunlight, warmth, and moisture, are the chief climatic *conditions of the development* of vegetable life; hence, corresponding to the climatic zones, there are well-defined *zones of vegetation*, the boundaries of which are approximately indicated by isothermal lines.

In high latitudes, however, though the mean annual temperature is below the freezing point, there may still be a varied vegetation, on account of the *heat of the summer*.

This is especially the case in the northern hemisphere, where the preponderance of land augments the summer heat, while it keeps down the annual average by intensifying the cold of winter.

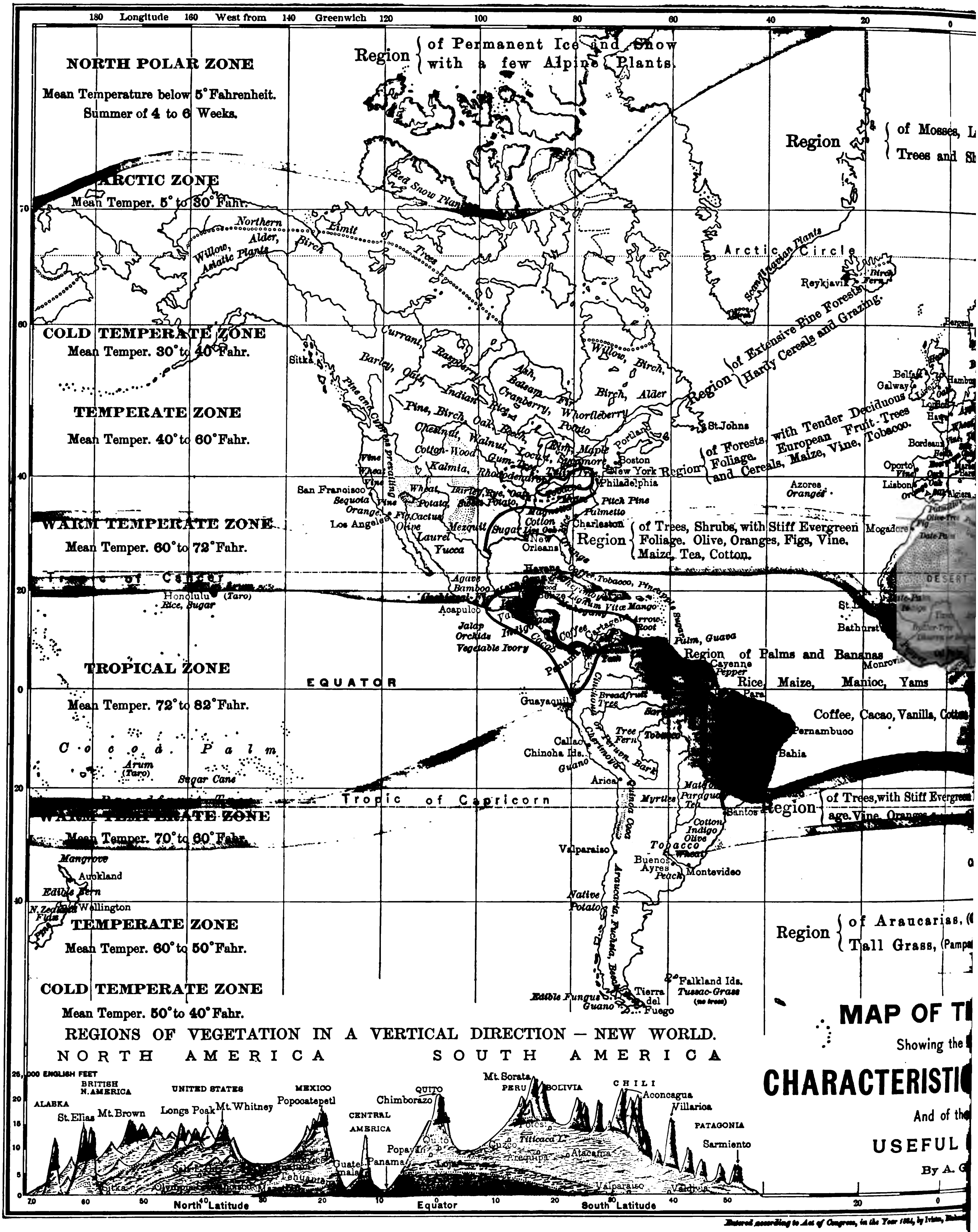
The successive zones, from the poles to the equator, show a marked increase in the number of species, and the luxuriance of growth, of the plants; with successively higher types in those which give the distinctive character to the vegetation of each zone.

The sunny tropical regions, which are most abundantly provided with warmth and moisture, display the greatest variety of types, and the utmost power of vegetable life. With few exceptions, all parts of the plant, whether stem, leaf, flower, or fruit, attain their greatest development here.

### II. Northern Cold Zones.

1. The North Polar Zone has a *mean annual temperature* of less than 5° Fahr., with a *summer* from four to six weeks in length. This region is almost devoid of vegetation, its flora consisting only of lichens, and a few diminutive Alpine plants which spring up and mature during the short summer.

2. The Arctic Zone, which may properly be designated the *Zone of the Mosses and Stunted Trees*, has a mean annual *temperature* varying from 5° Fahr. in the north, to 30° in the south.



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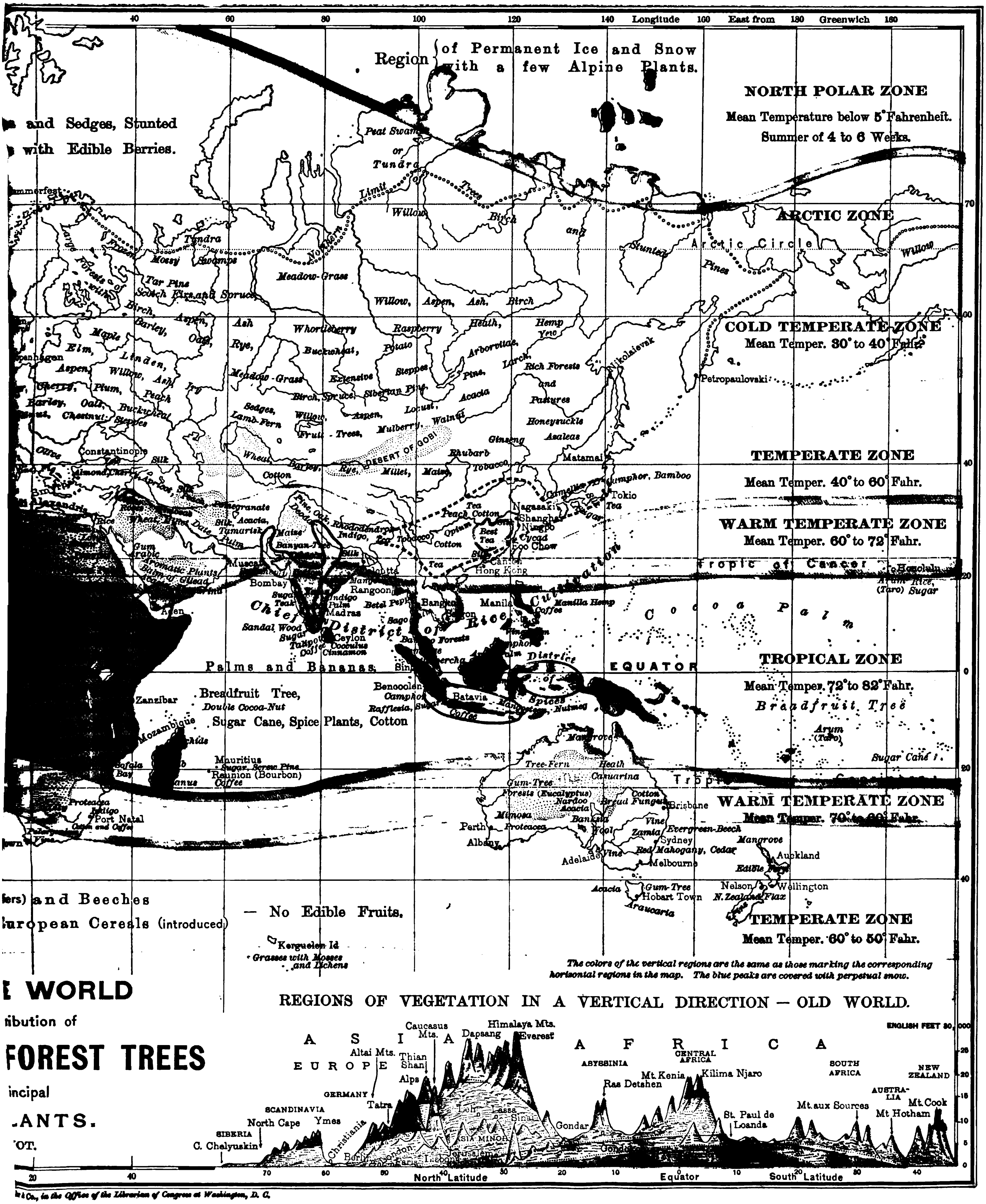

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The *vegetation* consists of but a few species of plants, and these are mostly of low types, mosses, lichens, sedges, and ferns, being the characteristic forms. Mossy swamps, called tundras, frozen during the greater part of the year, occupy a considerable portion of the lowlands of this zone, in both Europe and Asia.

The woody plants, — which include some varieties of willow and birch, azalea and rhododendron — in general trail along the ground, rising but a few inches above it; while the main stem, sometimes several feet long, is hidden among the mosses. Stunted trees — dwarf willow, alder, birch, and pine — are, however, found near the southern limit of this zone.

### III. Cold-Temperate Zone.

In the COLD-TEMPERATE ZONE, or the *Zone of the Conifers*, the *mean annual temperature* is from 30° to 40° Fahr. This zone is characterized especially by vast *forests of cone-bearing trees*, with evergreen, needle-shaped foliage; among which the pine, spruce, and fir are the predominant forms.

The willow, birch, and alder occur in greater numbers, and are of finer growth, than in the Arctic Zone; and the ash, the aspen, and the larch are occasionally found. There are, also, extensive treeless plains which are covered with meadow grasses and wild varieties of several useful plants, including flax, Indian rice, and oats.

The indigenous *fruits* are mainly acid berries, among which are the currant, cranberry, raspberry, and strawberry. The most hardy of the *cereals* — oats, barley, and rye — and the potato, the turnip, and some other edible roots, can be cultivated with success, but only in the more favored localities.

### IV. The Temperate Zone.

THE TEMPERATE ZONE, or zone of *Deciduous Trees*, has a *mean annual temperature* varying from 40° to 60° Fahr.

The *forests* — which cover vast areas in North America, eastern Europe, and the valleys and slopes of the Altai region and Manchuria in Asia — display not only a large number of species of stately and beautiful trees, but also a rich and varied undergrowth.

Among the most numerous trees are the oaks, elms, birches, maples, beeches, walnuts, and chestnuts; with the ash, larch, linden, alder, and sycamore — all of which lose their foliage in autumn.

The undergrowth consists chiefly of the wild apple, yew, holly, hawthorn, wild rose, honeysuckle, clematis, azalea, and rhododendron; varied by the wild grape, and some other climbing plants.

The *herbaceous vegetation* embraces nearly all those families of plants which furnish the staple articles of food among civilized nations (see page 111, Topic II., 3); together with a great variety of meadow grasses, and the hemp, flax, and tobacco.

The most numerous of the other characteristic orders are the umbelliferous plants, as the parsnip, carrot, and caraway; the cichoraceæ, as the lettuce and dandelion; and the cruciferæ, including the cabbage, turnip, radish, mustard, etc. The cruciferæ, which are almost confined to the northern hemisphere, are so numerous and varied as to give a distinctive character to the herbaceous flora of the temperate zone, especially in Europe.

*Exceptions* to the general abundance of vegetation in the temperate zone are found in the high barren plains and plateaus of western North America; the steppes of southeastern Europe, and of western Asia; and the deserts of Gobi and Shamo in eastern Asia. (See pages 24, II., 3., and 25; also 101.)

### V. Warm-Temperate Zone.

The WARM-TEMPERATE ZONE, or *Zone of Winter Foliage*, situated a little north of the Tropic of Cancer, has a *mean annual temperature* varying from 60° to 72° Fahr.

Its *characteristic vegetation* consists of trees and shrubs which retain their foliage throughout the year, though their growth is interrupted during the winter. The leaves are in general tough, stiff, and glossy; but lack the delicate tints which adorn the foliage of the deciduous trees in spring and summer, and the more gorgeous hues of autumn.

Here are found the live-oak, myrtle, laurel, and oleander, and the box, invaluable in the arts; with the cotton, the mulberry, and the olive; and tea, rice, and millet. Delicate fruits also abound, including the fig, orange, lemon, pomegranate, and almond, — all characteristic of this region, — and the choicest varieties of the vine.

### VI. Tropical Zone.

THE TROPICAL ZONE, or *Zone of Palms and Bananas*, has a *mean annual temperature* varying from 72° to 82° Fahr. The vegetation embraces an immense variety of species, in general remarkable for luxuriance of growth and great development of foliage. (See illustration, page 97.)

The *ferns*, which in other zones are small herbaceous plants, here assume the proportion of trees, rivalling the palms in the beauty of their crown of foliage; and the *grasses* far surpass those of middle latitudes in growth. To the latter class belongs the invaluable sugar-cane, and the gigantic bamboo which attains the height of 60 feet or more, while its hollow stalk furnishes the principal building material used in the East Indian Archipelago.

One of the most striking characteristics of the tropical forests is the great variety of trees which are mingled together, without the preponderance of any one family; while in temperate climes, extensive forests of a single family — as of pine, oak, beech, etc. — are common. Another distinguishing feature is the number of large flowering trees. The plants are perpetually covered with verdure, and many yield a constant succession of fruits and flowers.

The food-producing plants, indigenous to this zone, include the date, the sago, and the cocoa palm; the bread fruit and the cowtree; the plantain or banana; rice, and the sweet potato, yam, arum, and manioc.

The caoutchouc and gutta-percha, extensively employed in manufactures; the rosewood, mahogany, and ebony, so valuable in the arts for their rich color and the fine polish they are capable of receiving; with the cotton, coffee, and a multitude of other useful plants, are all natives of the tropical zone.

### VII. Southern Zones.

1. THE WARM-TEMPERATE ZONE resembles the corresponding zone north of the Equator, with the exception that it has few native food plants. The limited supply of moisture in Australia and South Africa, gives a peculiar meagreness to the general aspect of the vegetable world in those regions, which is, however, relieved to a certain extent by the brilliancy of the flowers. (Pages 104, 105.)

2. The TEMPERATE AND COLD-TEMPERATE ZONES, though having a higher average temperature than the corresponding regions of the north, show less luxuriance and variety of vegetation.

The former is characterized by forests of beech, and of the *araucaria*, which takes the place of the northern pines; but the latter has only the flora of the Arctic zone.

## III.—VEGETATION IN THE NORTHERN CONTINENTS.

### I. Similarity.

In the Arctic zone the vegetation is almost identical throughout the three continents, and they show a marked similarity in the cold-temperate zone. Advancing southward an increasing diversity is apparent, until, in the warm and tropical zones, the flora of each continent possesses a distinctive character.

### II. North America.

1. Temperate and Warm Regions. In the temperate region, this continent is distinguished from Asia and Europe, especially by the greater variety of its forest trees; and in the warm, by the number of large flowering trees. The most striking of these are the tulip-tree, the magnolias, the catalpas, and the locusts.

The arid plateaus of the warm zone are covered with thickets of the cactus, a family of plants peculiar to America; the yucca, a plant of the lily family; the agave or American aloe (century plant); and the mesquite, a sort of locust.

The distribution of forests, fertile prairies, and sterile plains, in the temperate and warm zones of this continent, is shown in the map *Vegetation of the United States*, on page 120, which gives also the staple articles of culture in the latter zone.

2. The tropical region is like South America in the luxuriance and variety of its flora, with nearly the same kinds both of trees and of herbaceous plants. (Page 104, II., 2.)

### III. Asia-Europe.

1. Western Asia and Europe *are distinguished* by the remarkable similarity of their flora, and the great variety of useful or beautiful plants which are indigenous.

The cork-oak, and the box; the mint, thyme, lavender, and other aromatic herbs; the gladiolus, iris, narcissus, carnation, and mignonette, are all indigenous to southern Europe.

The oleander, syringa, almond, and fine varieties of the cherry, are natives of Asia Minor; the peach, melon, cucumber, and hyacinth, of Persia; the choicest varieties of the vine and apricot, of Armenia; and the date-palm, fig, olive, mulberry, and damask-rose, of Syria. All of these are now naturalized in southern Europe.

2. The arid table-lands of *Iran* and *Mongolia* produce only thorny bushes, or stunted and almost leafless trees, and a few species of herbaceous plants, which afford sustenance for the herds of the nomadic inhabitants.

*Thibet*, being both dry and cold, has, except in certain favored spots, the flora of the cold-temperate and Arctic zones. Furze and other prickly shrubs, with the gooseberry, currant, hyssop, rhubarb, lucern, and assafœtida, are the most common plants; but two or three species of wheat, of buckwheat, and of barley, are indigenous in this table-land.

3. China is the home of the camphor laurel and the paper mulberry; of the tea plant, which abounds both in that country and in Japan; of some species of cotton; and of the sugar-producing sorghum.

4. India, Indo-China, and the Indian Archipelago display, in the lowlands, all the luxuriance and variety of vegetation which belongs to the tropical zone; while in the more elevated regions the trees, shrubs, and herbaceous plants of the warm-temperate and temperate zones abound. (See page 102, *Himalaya Mountains.*)

(1.) *Characteristics.* Along the coasts are thickets of mangroves, and a matted vegetation of forest trees, bamboos, coarse grasses, and creeping and climbing plants. The trees are covered with parasites, or air plants, of almost infinite variety, one of which, the rafflesia, a yard in diameter, is the largest flower known.

Palms are especially numerous, and occur in a great variety of species, some of which bear the largest leaves known. The banyan fig, and kindred species, abound, especially in India. These remarkable plants send down shoots from the branches, which take root and become new trunks, so that a single tree often produces a large grove.

(2.) *Useful Plants.* The teak, one of the most valuable of timber trees; the gutta-percha, camphor, sandal-wood, and ebony; the true indigo, now naturalized throughout the tropical zone; and a great variety of trees yielding dyes, spices, gums, and resins, are natives of this region. The spices, which are more especially characteristic of the islands, include the nutmeg, clove, cinnamon, cassia, ginger, and black pepper, the last being peculiar to the hottest portions of the Archipelago.

No part of the earth surpasses this region in the number of its native fruits and esculent vegetables. Among these are the bread-fruit, orange, mango, mangosteen, banana, cocoanut, sweet potato, arum, and yam; and different varieties of the cucumber, melon, and gourd family. The sago palm is also a native of the Archipelago.

5. Arabia. In the vast *deserts* of the interior, mimosas, and stunted prickly bushes which appear here and there in the sand, form the only vegetation; but the date palm abounds on the oases.

In the *mountains and valleys* of the south and east are many varieties of the acacia, from one of which the gum-arabic of commerce is obtained. Several species of trees and shrubs also yield fragrant balsams or resins, the odoriferous plants giving the especial character to the Arabian flora.

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## QUESTIONS ON THE MAP OF VEGETATION. (Pages 98, 99.)

Name the several zones of vegetation. In what continent is the tropical zone broadest? What parts of the New World are included in this zone? What parts of the Old World? What plants are especially characteristic of the tropical zone?

What are the principal coffee districts of the New World? Of the Old World?

In which of these is coffee native? Where is the principal spice district? Where is the chief district of rice cultivation? Where is the principal cotton region of the Old World? In what zone are the principal cotton and rice districts of North America? Are these plants native, or introduced in this region?

What forms the characteristic vegetation of the warm-temperate zone?

What part of the New World is included in the northern warm-temperate zone? What parts of the Old World?

What trees mark this zone in the eastern part of the United States? What plants are characteristic of the high western plateaus?

Name the principal plants of this zone in Europe; in Africa; in western Asia; in eastern Asia.

What plant is especially characteristic of the eastern portion of China?

What part of North America is included in the temperate zone? In what part of the continent is this zone broadest? In which continent does it lie farthest north?

What is the characteristic vegetation of the temperate zone? What extensive desert lies in this zone? What is the vegetation of eastern Asia in this zone? Of central and western Asia? Of Europe?

What trees characterize temperate America east of the Rocky Mountains? What trees grow on the Sierra Nevada and Cascade Mountains? Where are the only barren regions of North America? Where is the principal region of tobacco culture?

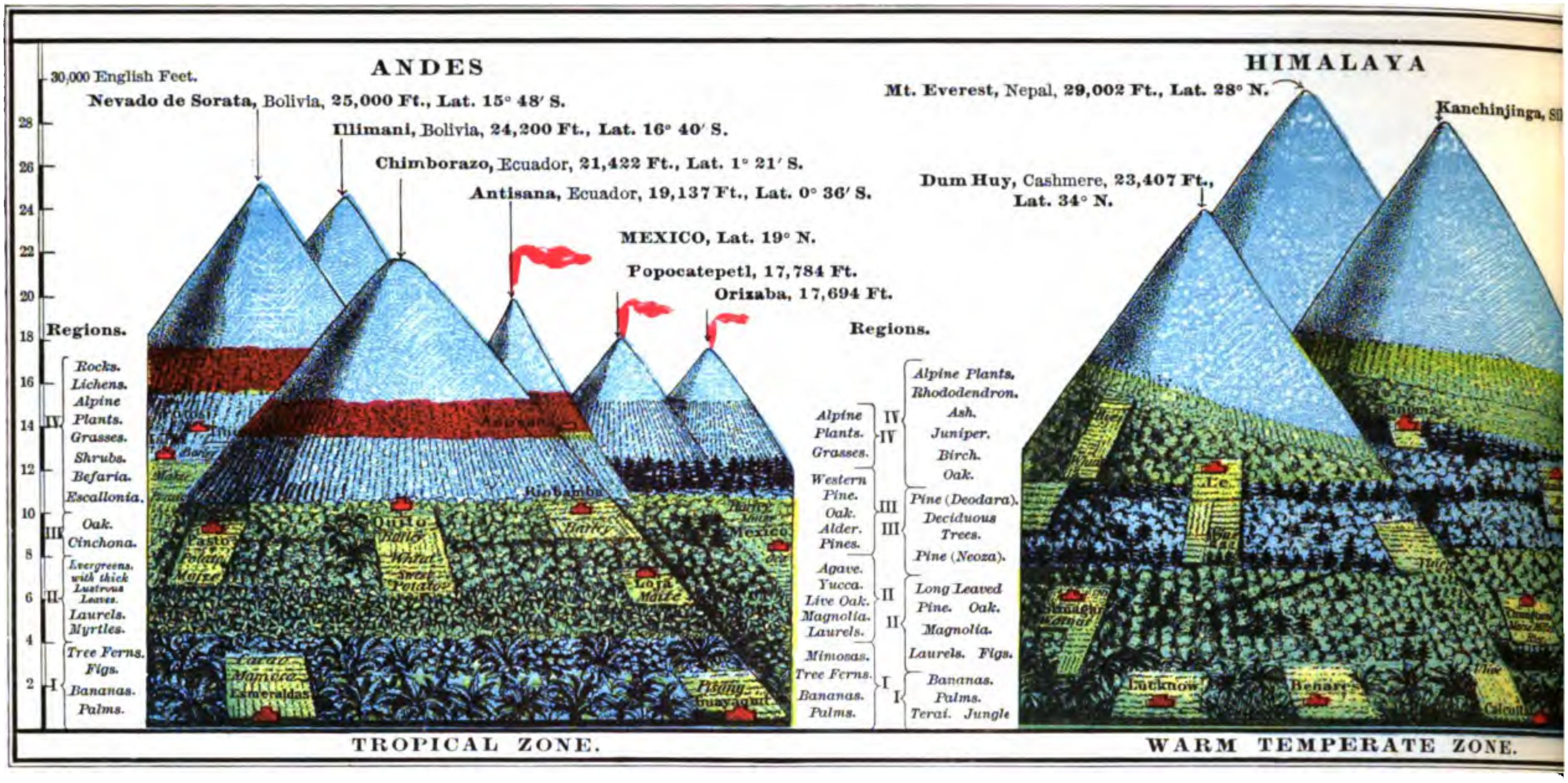
Where is the cold-temperate zone situated farthest north? What part of North America is included in it? Of Europe? Of Asia? What is the characteristic vegetation of this zone? What trees form the most extensive forests in this zone in North America? In Europe? In Asia?

What regions are included in the warm-temperate zone of the southern hemisphere?

What is the characteristic vegetation of this zone? What lands are included in the southern temperate zone? What are the characteristics of this zone?

What lands are included in the southern cold-temperate zone? What is the characteristic vegetation of this zone?

How do these southern zones compare in mean temperature with the northern? How do they compare in luxuriance and variety of vegetation? In useful plants?


30,000 English Feet.
28
26
24
22
20
18
16
14
12
10
8
6
4
2
ANDES
Nevado de Sorata, Bolivia, 25,000 Ft., Lat. 15° 48′ S.
Illimani, Bolivia, 24,200 Ft., Lat. 16° 40′ S.
Chimborazo, Ecuador, 21,422 Ft., Lat. 1° 21′ S.
Antisana, Ecuador, 19,137 Ft., Lat. 0° 36′ S.
MEXICO, Lat. 19° N.
Popocatepetl, 17,784 Ft.
Orizaba, 17,694 Ft.
Regions.
IV Rocks. Lichens. Alpine Plants. Grasses. Shrubs. Befaria. Escallonia.
III Oak. Cinchona.
II Evergreens, with thick Lustrous Leaves. Laurels. Myrtles.
I Tree Ferns. Figs. Bananas. Palms.
Quito
Pasto
Riobamba
Loja
Mexico
Esmeraldas
Guayaquil
Regions.
IV Alpine Plants. Grasses.
III Western Pine. Oak. Alder. Pines.
II Agave. Yucca. Live Oak. Magnolia. Laurels.
I Mimosas. Tree Ferns. Bananas. Palms.
IV Alpine Plants. Rhododendron. Ash. Juniper. Birch. Oak.
III Pine (Deodara). Deciduous Trees. Pine (Neoza).
II Long Leaved Pine. Oak. Magnolia. Laurels. Figs.
I Bananas. Palms. Terai. Jungle
HIMALAYA
Mt. Everest, Nepal, 29,002 Ft., Lat. 28° N.
Kanchinjinga,
Dum Huy, Cashmere, 23,407 Ft., Lat. 34° N.
Lucknow
Benares
TROPICAL ZONE.
WARM TEMPERATE ZONE.

VERTICAL DISTRIBUTION OF

## IV. — VEGETATION AT DIFFERENT ALTITUDES.

### I. Vertical Zones of Vegetation.

In consequence of the diminution of the temperature with increasing altitude (see page 72, Topic II., 2), vertical zones of vegetation may be distinguished, with characteristics no less marked than those of the horizontal zones. The observer, passing from the base to the summit of high mountains in any latitude, finds variations in the character of the plants similar to, though not identical with, those observed in advancing to higher latitudes.

**The above diagram is designed to furnish a graphic representation of the vertical distribution of vegetation in the different latitudes. The *Andes* serve as the type for mountains in the tropical zone; the *Himalayas*, for those in the warm-temperate; the *Alps*, for those in the temperate proper; and the *Scandinavian Alps* for the mountains of the cold-temperate zone.**

### II. The Andes and Mexican Mountains.

1. Tropical Region. Below 4,000 feet of altitude, the vegetation on the slopes of the Andes consists of families of plants belonging to the tropical zone; and displays the luxuriance of growth, the abundance of foliage, and the immense variety of species which is especially characteristic of tropical America. In the *lower half* of this region, the palms and the various species of the banana are the dominant types; in the *upper half*, the tree-ferns and the fig-family are the most numerous and characteristic trees.

2. Warm Region. Between 4,000 and 8,000 feet the vegetation is that of the warm-temperate zone of the New World, and is characterized by its thick, lustrous, evergreen foliage. The laurel, myrtle, evergreen-oak, and magnolia among trees, and the agave, yucca, and cactus among herbaceous plants, give to this region its distinctive character.

3. Temperate Region. From 8,000 to 10,000 feet those families of trees occur which compose the deciduous forests of the temperate zone; but the character of the species is modified by that uniformity of temperature throughout the year which distinguishes the tropical zone at every altitude. In this region, and in the upper part of the preceding, grows the cinchona, so highly valued for the quinine and other remedies obtained from it.

4. Cold Region. Above 10,000 feet of altitude we find only the vegetation belonging to the cold-temperate, arctic, and polar zones. Dwarf trees and shrubs, grasses, and alpine flowering plants occur in succession, and are followed by a region where only lichens grow upon the naked rock, above which are the fields of perpetual snow.

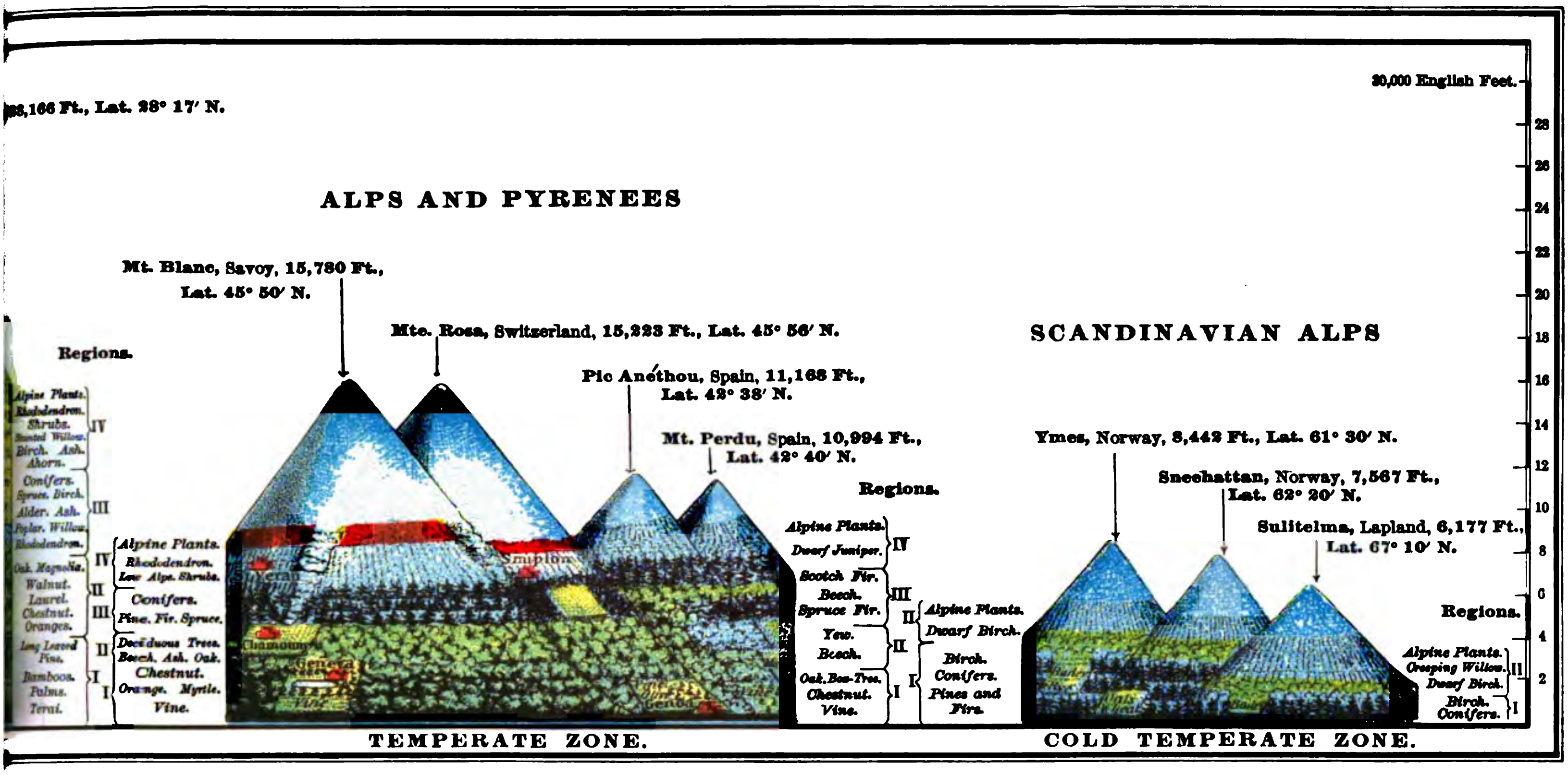
In the *Andes of Bolivia*, where the snow line is higher than under the Equator, these several zones each extend a little higher than in the Equatorial Andes. On the *mountains of Mexico*, the same succession of zones, and similar species of plants, are generally found. There is, however, an exception in the third, or temperate region, where the western pine abounds, and the Alpine vegetation reaches the snow line.

### III. The Himalayas.

1. Tropical Region. These mountains *are situated* on the southern boundary of the warm-temperate zone. On their southern slope, which is completely sheltered from polar winds, they have a narrow belt of tropical vegetation. It extends to the altitude of 2,000 feet in the northwest, and 4,000 feet in the southeast; and is marked by the various species of plants belonging to the flora of India. The palms, bananas, figs, and bamboos grow here with scarcely less luxuriance than in the lowlands.

**At the foot of the mountains is a narrow belt of marshy jungle, known as the Terai, covered with an almost impenetrable tangle of tropical vegetation, and uninhabitable by reason of its malarious climate.**

2. The warm region extends to the altitude of 7,000 or 8,000 feet, and is characterized by those families of plants which occur throughout the warm-temperate zone of the northern hemi-



# NTS IN VARIOUS LATITUDES.

sphere. The oaks, especially, of which twenty-five species grow here, attain great size. The long-leaved pine, which is characteristic of the Himalayas, also grows luxuriantly.

3. Temperate Region. Above the warm region, extending to an altitude of 11,000 or 12,000 feet, there is a belt of deciduous trees, mingled with pines, cedars, and other conifers. All the plants are closely allied to those which characterize the temperate zone of both Asia-Europe and North America. The poplar, willow, maple, alder, ash, and birch are all abundant here; and rhododendrons grow in great variety and beauty.

4. Cold Regions. Above the last, reaching to the height of from 14,000 to 16,000 feet, is a region corresponding to the Arctic zone, where the vegetation consists of dwarf trees, stunted shrubs, and grasses. These are succeeded by small, bright flowering Alpine plants, which extend to the line of perpetual snows.

## IV. The Alps and Pyrenees.

1. Warm Region. These mountains, situated on the southern boundary of the temperate zone, have, upon their southern slopes, a narrow belt of vegetation belonging to the warm-temperate zone. It is characterized by the fig and the olive, which do not, however, extend above the altitude of 500 feet.

2. Temperate Region. In this region, extending to the altitude of 2,500 feet, there is a belt of deciduous trees — characterized by the chestnut and oak, and the vineyards, so numerous in Switzerland — succeeded by conifers, which extend to about 6,000 feet. Both belts are more strongly marked than in the Himalayas, where the deciduous trees and conifers are largely intermingled.

3. Cold Region. The conifers are succeeded by rhododendrons, and diminutive Alpine plants, extending to the height of 9,000 feet; beyond which are the perpetual snows. This Alpine flora is marked especially by very short stems, brilliant flowers, and large roots.

**Owing to the warmth of the summer, these mountains and the Himalayas show, at the verge of the perpetual snows, a much richer flora, both in number of species and beauty of forms and colors, than the corresponding region of the Andes, where the uniformity of temperature throughout the year limits the vegetation to a few varieties of plants which are mostly of low types.**

## V. The Scandinavian Alps.

These mountains, situated in the cold-temperate zone, show only a region of conifers and birches, succeeded by a belt of dwarf shrubs and Alpine plants, the characteristic flora of the Arctic zone. In the south the conifers extend to about 2,800 feet, the birches to 3,500; but the altitude to which they grow diminishes rapidly towards the north.

## VI. Cultivated Plants.

The limits of the various species of cultivated plants, in the different regions indicated above, are no less marked than those of the spontaneous vegetation. They furnish a striking illustration of the advantage of the varying seasons of the warm-temperate zone over the uniformity of the tropical.

*On the Andes* and the *Mexican mountains*, from latitude 16° south to 19° north, the average upper limit of the culture of the cereal grains and the potato is about 10,000 feet; but in the plateau of Bolivia, maize will mature somewhat higher, and barley as high as 13,000 feet above the sea level.

In the *Himalayas*, between 28° and 34° north latitude, rye and barley are successfully cultivated at the altitude of 14,000 feet, and wheat at 12,000; while turnips and some other edible roots succeed as high as 16,000 feet.

In the *Alps and the Pyrenees*, latitudes 42° to 45° north, the culture of the cereals terminates at from 4,000 to 6,000 feet of altitude. In the *Scandinavian Alps*, in latitudes 61° to 67°, barley and oats grow only near the sea level; though rye may succeed as high as 600 feet above the sea.

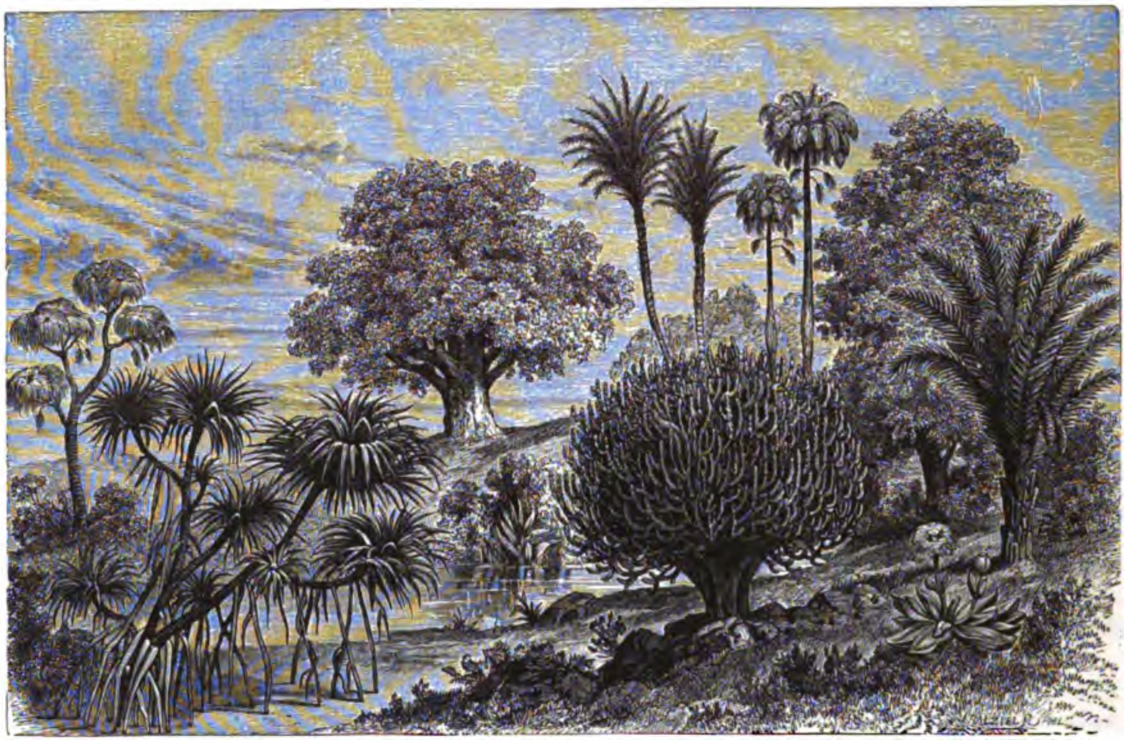
# V. — VEGETATION OF THE SOUTHERN CONTINENTS.

## I. Africa.

1. Equatorial Africa. Africa, the dryest of the tropical continents, and the hottest of all, has, in a large portion of its area, a comparatively meagre flora.

Equatorial Africa, however, from about 15° north latitude to 20° south, has a luxuriant vegetation, with a general resemblance in types to those of India; yet, even in this most favored zone of the continent, we nowhere find such dense, interminable forests as characterize tropical America. The wooded lands, though extensive, are separated by large treeless tracts, which are covered with tall sedges and gigantic grasses with branching stems.

On the borders of this equatorial region, groves of acacias, mimosas, and cassias, and stunted bushes form a transition to the arid, treeless plateaus of South Africa and the deserts of Sahara.



CHARACTERISTIC PLANTS OF AFRICA.

*Palms* are numerous, but are of less varied species than in other tropical lands. The doom-palm, remarkable as being the only species with a branching stem (see illustration), is peculiar to the basin of the Nile, where it is accompanied by the wine-palm, with its long flower-clusters, and the deleb-palm, with its singularly swollen trunk. The oil-palm is found only on the coasts of the Gulf of Guinea.

The musanga, kindred to the bread-fruit of the East Indies, and the yam tribe, are plentiful throughout equatorial Africa; and coffee is indigenous in the plateau of Abyssinia.

The alluvial plains on the western coast are covered with thickets of mangroves and other trees, intermingled with many poisonous plants. On the higher lands are groves of the baobab, a remarkable tree, which, though rarely more than fifty or sixty feet high, has a trunk sometimes over thirty feet in diameter. Solitary pandanus trees rise here and there: and the butter-tree, peculiar to Africa, abounds. The tamarind, a flowering tree similar to the locust, and valuable for its timber, grows throughout equatorial Africa.

2. Northern Africa. *The Mediterranean region* of Africa bears a marked resemblance to southern Europe, more than half the plants which compose the flora of the former being found in the latter.

*South of the Atlas region*, and upon the oases in the midst of the desert, are extensive groves of the date-palm which furnishes a large part of the food of the inhabitants of the country.

The *plants of the Sahara* are few, and consist mainly of prickly and thorny bushes and stunted shrubs of the same general character as those of Arabia; yet some portions yield a harsh, prickly grass, valuable as food for the camel.

3. South Africa. The flora of the high, arid, southern part of Africa differs entirely from that of other portions of the continent; and includes an immense number of species, many of which produce flowers of the most gorgeous hues.

Thorny and prickly shrubs with meagre foliage, and fleshy and succulent plants, are the most numerous types. The latter include the house-leek tribe, the mesembryanthems, and the leafless euphorbias which correspond to the cactus family of the New World. (See illustration below.)

The *flowering plants* include 300 different species of heaths, and over 200 proteas, both of which are distinguished by their small, narrow, leathery, evergreen leaves, and their large clusters of brilliant flowers. Aloes, in great variety, grow in thickets, which form the so-called "bush" of South Africa. Many beautiful plants of the oxalis, or wood-sorrel tribe, are found here; with nearly every known species of gladiolus, and a great number of geraniums (Pelargonium).

In the dry season the high interior plateaus have almost the aspect of a desert, bearing only a few stunted shrubs, with some succulent plants and mimosas along the borders of the streams. Immediately on the commencement of the rainy season, however, the germs, bulbs, and roots, which have lain dormant in the parched soil, send forth their shoots, and the country is quickly covered with a brilliant and varied vegetation.

## II. South America.

1. General Character. The wealth of moisture which characterizes the continent of South America, together with its tropical temperature, secures to it a vegetation unsurpassed in luxuriance of growth.

The *especial characteristics* of the South American flora are its great variety of species and remarkable development of foliage and the brilliancy of its blossoms, with the great number of large flowering trees.

2. Forests within the Tropics. Among the *most numerous plants* are the palms and bananas, the tree ferns, the fig family, — the kindred of the banyan tree, — and the mimosas.

Reeds and grasses of great height, and a multitude of herbaceous flowering plants, including the beautiful Victoria Regia (see illustration, page 97), enrich the flora, especially in the vicinity of the streams. Passion-flowers, and other slender creepers, twine round the lower plants; while other vines, often as thick as cables, climb the trees, and stretch from bough to bough, intermixed with a multitude of parasitic plants, bearing the most brilliant flowers.

This richness of vegetation, which finds its parallel nowhere, except in a comparatively small portion of Asia, extends over the larger part of the continent of South America, and the lowlands in the tropical portions of North America. It characterizes especially the plains of the Amazon basin and the adjacent portions of the Orinoco and La Plata basins.

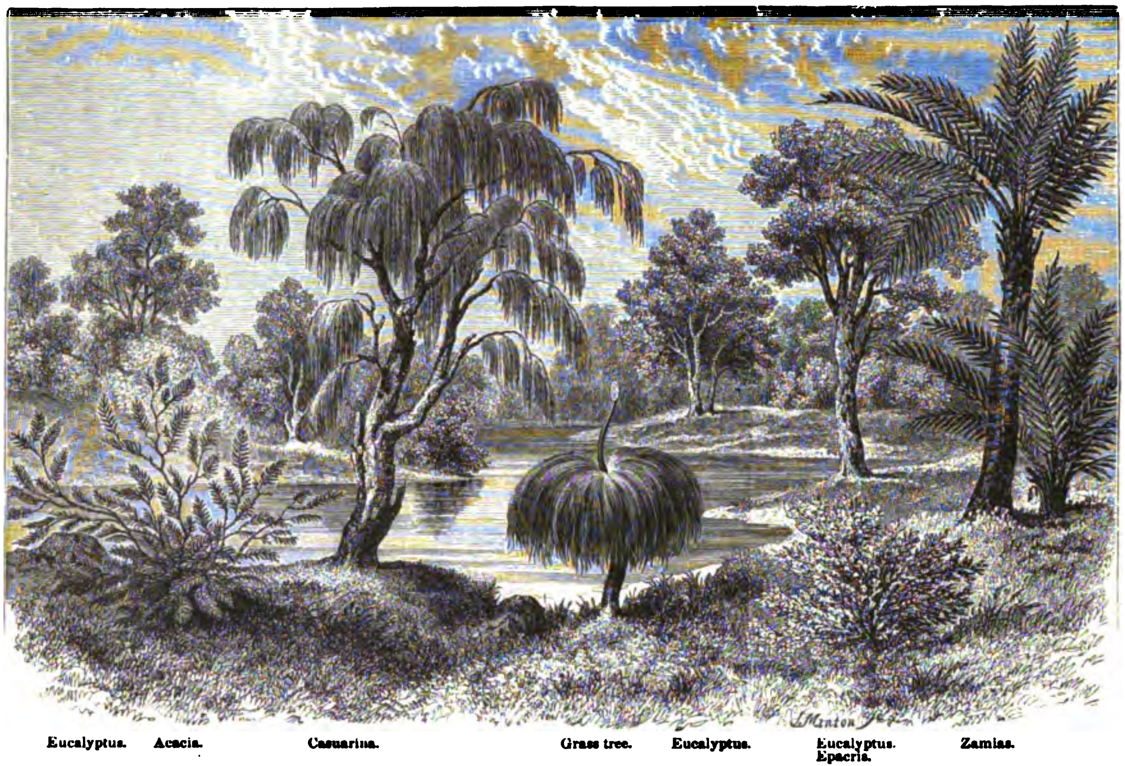
Included in this tropical flora are the mahogany, rosewood, and other trees furnishing valuable timber or dyes; the invaluable caoutchouc; the coca of the Andes, whose leaf possesses powerful stimulant and narcotic properties; the tobacco and the capsicum, or red pepper; the cinchona, and many other medicinal plants; and a great variety of plants yielding food, perfumes, balsams, gums, and resins.

Among the *esculent productions* are the yam, whose large tuber replaces the potato in hot climates; the cassava, from the root of the manioc; the fruits of the Bertholletia, — known in commerce as the "Brazil-nut;" the milky juice of the cow-tree; the delicious cherimoya and pineapple; the fruit of the cacao-tree, from which chocolate is prepared; the vanilla, so valued for its perfume; and the algaroba bean, the fruit of a kind of acacia. The yerba-maté, a species of holly, the leaves of which are used as tea, is a native of the Paraguay basin.

3. Exceptional Regions. In the dryer portions of the *table-land of Brazil* (see *Map of the Rains*), the vegetation consists of stunted deciduous trees and extensive grassy plains, interspersed with myrtles and other shrubs. The agave and the cactus — the latter peculiar to the New World — also abound in these hot, arid plains.

The *Llanos*, of the Orinoco basin, are covered with tall grasses, intermingled with lilies and other bulbous flowering plants in great variety and beauty, with here and there groves of palms and mimosas.

The *Pampas*, within and south of the La Plata basin, are covered with tall grass, clover, and thickets of gigantic thistles; while the barren plains of *Patagonia* yield only coarse grass, growing in tufts, and the stunted, thorny bushes characteristic of desert lands.



CHARACTERISTIC VEGETATION OF AUSTRALIA.

*West of the Andes*, throughout the zone of the trade-winds, the scarcity of moisture is such as to render the soil, in general, barren, except where irrigation is resorted to. Chili, in the region of the return-trades, is well supplied with moisture, and has a rich flora. Extensive forests clothe the mountain slopes, including majestic trees of many kinds, which support a beautiful growth of climbing and parasitical plants.

The araucaria imbricata, a species of fir tree with large cones enclosing edible seeds, grows in the Andes of Chili and Patagonia, and yields a large amount of nutriment invaluable to the native inhabitants. The potato, now cultivated so extensively in Europe and North America, is indigenous to southern Chili; also the fuchsias, the much admired ornaments of our green-houses and gardens.

### III. Australia.

1. General Character. The flora of Australia, though including some species kindred to those of southern Africa and South America, is yet, in general, of a very exceptional character. Many entire orders of plants are known only in Australia; and the representatives of those families which are found elsewhere, here appear in new and peculiar forms. Scarce an edible fruit, grain, or vegetable of any sort, is indigenous in this remarkable continent.

The scantiness of foliage, and the sombre hues and stiff, lustreless leaves of the almost shadeless forests, unvarying in tint from season to season, — and composed of scattering trees, with little or no undergrowth, — give an aspect to the Australian landscape unlike that of any other quarter of the globe.

2. Forests. The *myrtle tribe*, including the eucalyptus (see illustration), and other trees with beautiful flowers of white, purple, yellow, and crimson, are the most numerous of Australian trees. They grow with rapidity, and frequently attain great size, some of the eucalypti being over 400 feet in height, the tallest of known trees. Their leaves are usually elongated and dispersed, and hang down vertically, thus presenting only the edge to the light, and casting but little shadow.

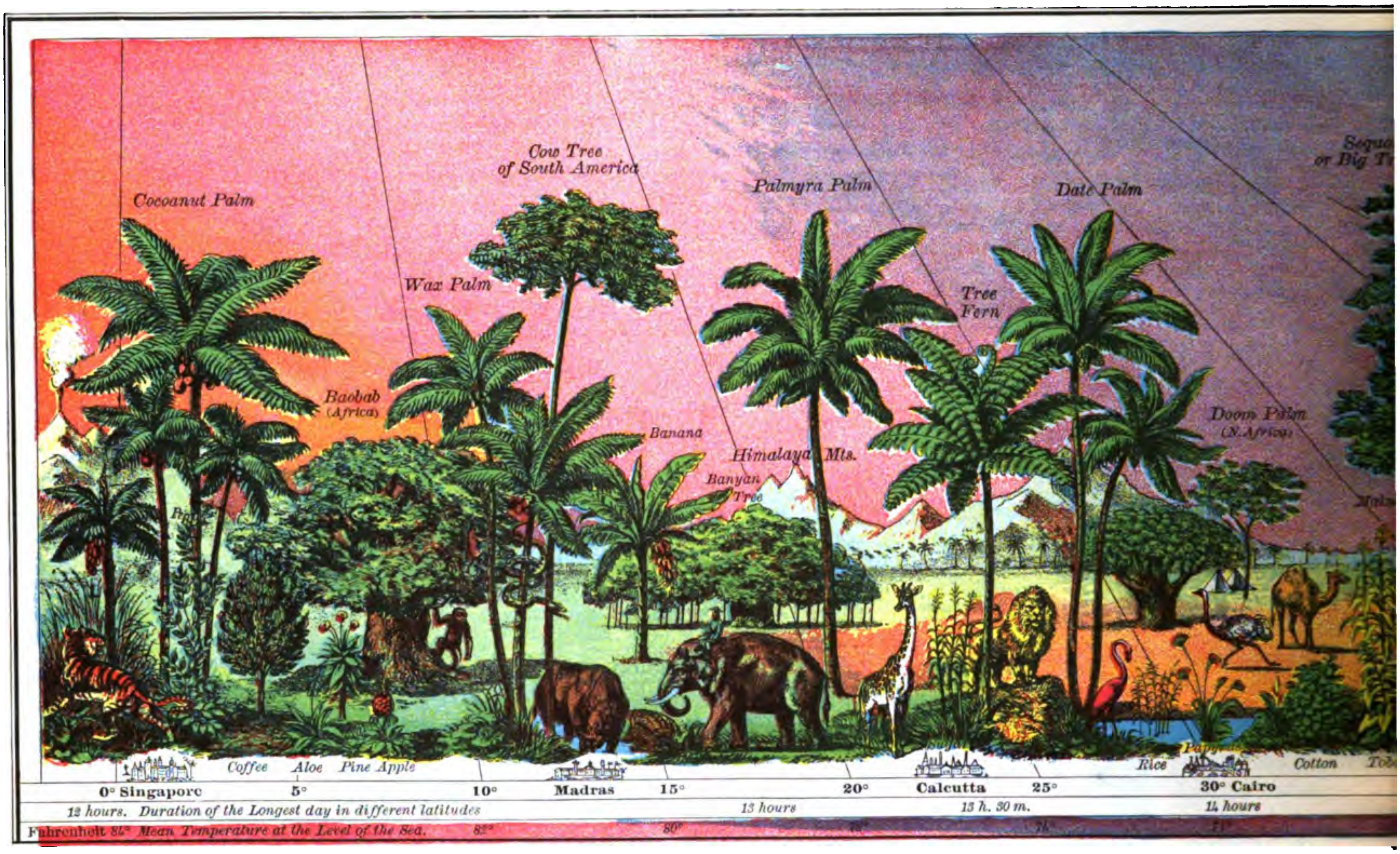
Next in point of numbers are the *acacias*, of which there are nearly 100 species. The footstalks, placed with their edges towards the stem, replace leaves in the larger number of these singular plants. They, chiefly, form those impenetrable thickets, called scrub, which cover vast tracts of the dry interior.

The *casuarinas*, or marsh-oaks, producing excellent timber, have long, slender, wiry branches, with scale-like sheaths instead of leaves; and combine with the eucalyptus and acacia to give that singular aspect to the Australian landscape, remarked by travellers.

3. Local Flora. The epacris (a flowering shrub similar to the heaths), with scarlet, rose-colored, and white blossoms; proteas in great variety and beauty; a gigantic lily, with brilliant crimson flowers; and the zamia, having the appearance of a dwarf palm, — are all abundant in *southeastern Australia.*

*In the southwest* the grass tree, with a tall trunk crowned with tufts of long, grassy leaves, grows on the sandy plains; and plants with dry, everlasting blossoms are numerous. Reeds of great size often cover the moist lands along the streams; and open grassy plains are frequent in all the southern part of the continent

*In the northeast* some peculiar varieties of the fig family grow, the pandanus flourishes in the neighborhood of the sea, and a few species of palm are found along the eastern coasts. On the *northern coasts* are many species of plants belonging to the flora of the Indian Archipelago, among others the cabbage palm, some species of nutmeg, and the sandal-wood.



ASPECTS OF NATURE

## VI.—ASPECTS OF NATURE IN DIFFERENT ZONES.

**Explanation of the Diagram.** The above diagram is designed to represent the different climates of the globe, from the Equator to the northern limits of the continents, about latitude 72°; and to exhibit, in the varying angle at which the Sun's rays strike the surface of the Earth (see page 70, Topic I., 2), the grand cause of the diversity, in light, in temperature, and in the development of life, both vegetable and animal.

The *oblique* lines which traverse the diagram, represent the increasing obliquity of the Sun's rays, from equatorial to polar latitudes; and the *colors of the background*, varying from fiery red at the left to cold blue at the right, show the diminution in the intensity of heat and light consequent upon the greater obliquity. The duration of the longest day, and the mean annual temperature, at the different latitudes, are also given.

Some of the principal animals and plants of all the climates are given in their proper positions, thus showing the effect of light and heat upon their distribution. Beneath, in their correct latitudes, are some of the principal cities of each climate.

### I. The Tropical Regions.

1. Law of Development of Life. Throughout the entire realm of nature, in the animal world as well as in the vegetable, the *development of life* increases in energy, and in the variety and perfection of the types, with the increasing intensity of light and heat, from the poles to the equator.

2. The Vegetable World. Within the tropics, under the stimulating rays of a vertical Sun, grow the most dense and varied forests, the most expanded foliage, and the largest and the most brilliant flowers. Here, also, are found the most delicious fruits, the most powerful aromatics, the greatest variety of plants capable of affording sustenance to man, and the largest number of those which contribute to the luxuries of civilized life.

3. The Animal World. In the tropical regions, also, are found the greatest variety of species of land animals; with the highest types, the greatest stature, the most intense activity, and the keenest intelligence exhibited in the brute creation.

This zone is the home of the gigantic elephant and giraffe; of the lion and the tiger, the most powerful of all the beasts of prey; and of the gorilla, chimpanzee, and orang-outang, of all animals most like to man in figure and organization.

Here, also, are the ostrich, the largest and most powerful of birds; the condor, surpassing in size all other birds of flight; and the humming-birds of South America, the smallest of the feathered tribes, unsurpassed in brilliancy of coloring, rapidity of motion, and grace of form.

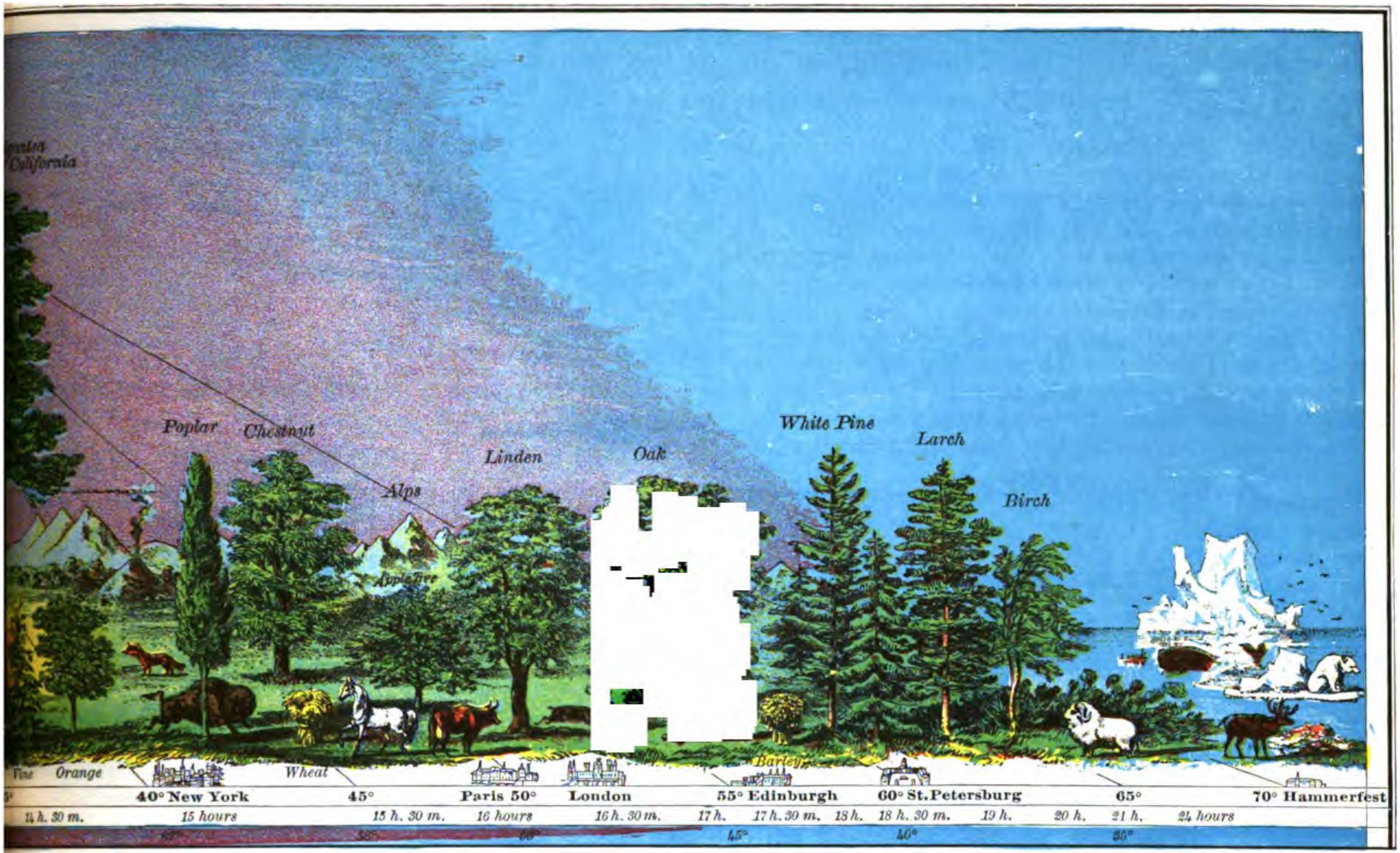
In the same zone are those enormous reptiles, the crocodile and the boa-constrictor, with the hooded snakes and other serpents of most deadly venom; and insects of all sizes in indescribable profusion.

### II. Temperate Regions.

1. In the Warm-Temperate Zone, though the Sun never reaches the zenith, yet during the long summer his rays are almost vertical; while the winter is so mild that snow and ice are of rare occurrence.

Here the *vegetable world* is less prodigal in species, and less luxuriant in growth, than in the tropical regions; still, verdure is continuous throughout the year, and fruits and flowers succeed each other almost without interruption.

The *animal world* shows a similar, though less marked, decrease in the exuberance of life. The higher orders are less numerous,



# DIFFERENT LATITUDES.

the individuals less gigantic and powerful; yet the antelopes, among the most graceful of animals, and the camel, one of the most useful, especially characterize this zone.

2. In the TEMPERATE ZONE, farther from the tropics, and receiving the Sun's rays with greater obliquity, all the forms of *vegetable growth* are more modest than in the preceding. The forests are less dense and varied, the foliage is less luxuriant, and flowers of brilliant hues are confined to shrubs and herbaceous plants.

Though useful plants are numerous, yet scarce a species is of value in its spontaneous growth; and, above all, the long dormant season, when the trees and shrubs are bare and apparently lifeless, stamps the vegetation of this zone with an aspect of inferiority.

The *animal world* still shows a large number of noble species; yet there are some orders which, like the plants, are dormant during the winter; while many of the birds migrate to warmer climes.

Here—associated with deciduous forests, boundless fertile prairies, and arid steppes—are the bear, the wolf, the lynx, the bison, and many species of elk and deer. Here is the home of the horse, the ass, and many varieties of oxen, sheep, and goats,—those animals which, domesticated by man, have accompanied him to all climes, adapting themselves to all circumstances.

The American turkey, the European pheasant, and the Asiatic parents of many of our domestic fowls, also belong to the temperate zone; together with a multitude of song birds, whose sober plumage, contrasting so gloomily with the brilliant colors of their neighbors of the tropics, is compensated by the sweetness of their notes. Here, also, is the home of the honey-bee, and of the silkworm, almost the only insects directly useful to man.

## III. Cold Regions.

1. GENERAL ASPECT. In these regions, where the sun is always low, and in winter is above the horizon but a small part of the time, all nature becomes increasingly monotonous. The conifers, with their stiff forms and sombre hues, impart a dreary aspect even to the summer landscape; and, during the long winter, all life seems suspended.

2. THE ANIMAL WORLD, however, is more rich and varied than the vegetable.

In the *zone of the conifers* we meet the great moose and the brown bear, the beaver and other rodents, in large numbers; the sable, the mink, the ermine, and a host of other animals whose fine, soft furs form one of the main resources of this inhospitable clime.

In the *Arctic Zone*—where these forests give place to dwarf trees, stunted or creeping shrubs, mosses, and lichens—the reindeer, the musk-ox, and the white bear are the only representatives of the larger land animals, though the smaller furry tribes are still numerous.

The sea, however, more genial in its temperature than the land, swarms with living creatures of innumerable species, among which are the largest representatives of the animal kingdom.

The whale, the walrus, and the seal, inhabit the Arctic seas; with every grade of marine life, down to the animalculæ, which are so numerous as to give their color to great areas of sea-water; and water-fowl, without number, and of many varieties, enliven the icy shores.

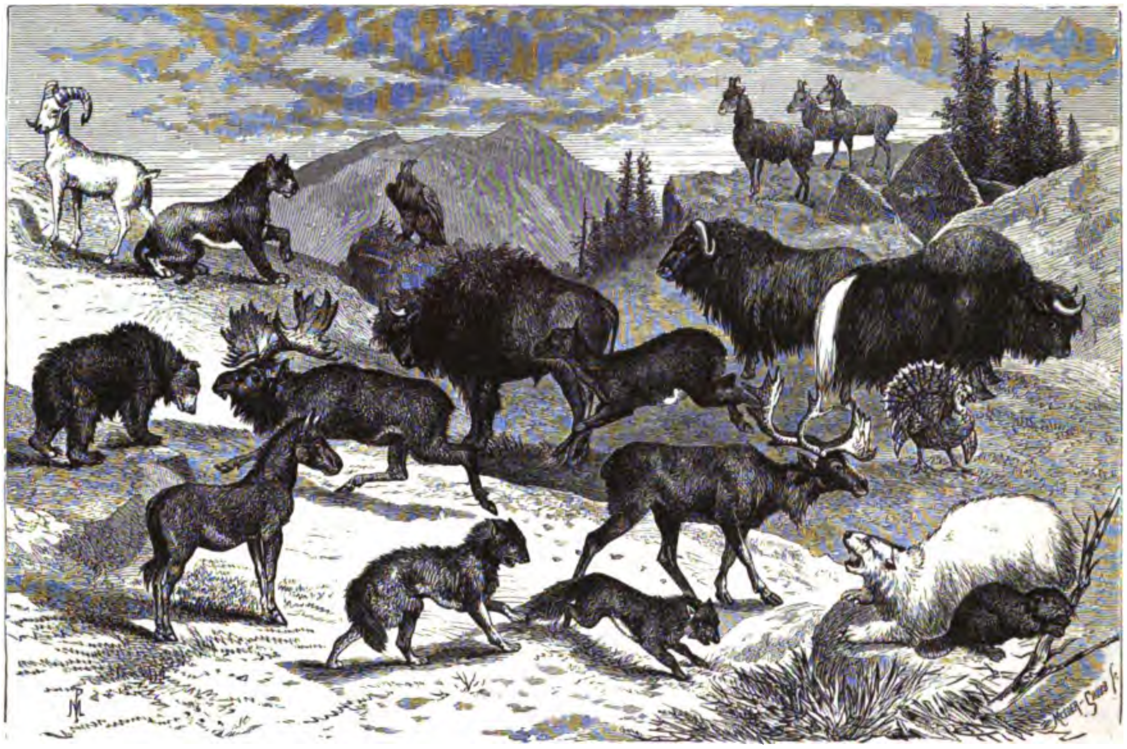
## VII. — ANIMAL LIFE IN THE NORTHERN CONTINENTS.

### I. General Similarity.

1. Extent of Resemblance. The three northern continents — so like in their general climatic conditions, and in their vegetation — are, in the main, inhabited by the same orders and genera of animals, though, as in the vegetation, few species are identical. Insects, reptiles, birds, and mammals, all appear in kindred species, so like, in many cases, that the superficial observer would declare them to be identical.

2. Orders Common. Antelopes, of different kinds, are found in each of the three continents; and the reindeer, the elks, and some other kinds of deer, are so similar that even zoölogists are in doubt whether they are really of distinct species.

The bison and musk-ox of America, also, are closely related to the aurochs of Europe and the yak and other oxen of Asia; and the big-horn sheep of the Rocky Mountains finds its kindred in the moufflon of Southern Europe, and the argali and other sheep of Western and Central Asia. Goats of several species, and the wild boar, though wanting in America, are common to Europe and Asia.



CHARACTERISTIC ANIMALS OF THE NORTHERN CONTINENTS.

The cat tribe abounds in all three continents; also bears, wolves, dogs, and foxes. The rodents, or gnawers (beavers, rabbits, squirrels, rats, mice, etc.); and the minks and ermines, with others of their tribe, are but slightly different in the several continents.

### II. North America.

1. Characteristic Animals. North America, with its wealth of moisture and abundance of vegetation, and its vast rivers and lakes, is characterized by the predominance of the herbiverous over the carnivorous animals; by the great number of rodents, many of which are aquatic animals; and by its innumerable water-fowls.

Nearly all the orders of the Old World, including both web-footed birds and waders, are represented in North America, with many peculiar to the New. Other birds are very numerous, among which are the turkey, peculiar to this continent; various kinds of pigeons; the quail, the partridge, and a great variety of other game.

The deer — the ruminant (cud-chewer) of the forest — occurs in a variety of species, and in great numbers; while the antelope and the bison roam the high western plains. The bisons feed and move in immense herds, sometimes numbering scores of thousands.

2. Other Species. The brown and the white bear inhabit the Arctic regions; the grizzly bear, the largest and most ferocious of its kind, is found in the Rocky and Sierra Nevada mountains; and the black bear, in the forests of the East. Dogs are indigenous in the far North, where some varieties have been domesticated.

The puma, or American lion — commonly called the panther — is the most powerful animal of the cat tribe belonging to North America, and replaces in this continent the lion and tiger of Asia.

### III. Asia-Europe.

1. Asia is especially characterized by the great number of animals capable of domestication, which are found in every part of the continent. The horse, the ass, and the yak; the valuable Cashmere and Angora goats; several varieties of sheep; and the Bactrian camel, with two humps, are all indigenous in Central Asia, and all were already the servants of man at the dawn of history.

Southern Asia has the swine, and the gigantic elephant; the zebu and the buffalo, early domesticated by the native man, together with a number of other oxen still wild. Western Asia has the dromedary or Arabian camel, with one hump; the Syrian ox, and several sheep and goats; and northern Asia has the reindeer.

2. Tropical Asia, which includes the Indian Archipelago and the adjacent peninsulas, is the home of the *highest orders* of animals, though their species are less numerous than in Africa.

Here are found the orang-outang, so like to the human form that he is called by the Malays the *man of the woods;* many species of apes and monkeys peculiar to Asia; and the Indian elephant, the rhinoceros, the tapir, and the wild boar.

The *carnivorous animals* are numerous and powerful. The royal tiger, the handsomest and most formidable of these, inhabits the jungles of Hindostan; leopards and panthers are common, and the lion is seen in some parts of Indo-China.

Four species of bears are found in India, and wolves, foxes, hyenas, and jackals occur nearly everywhere.

The roussette bat, the largest known species, the body of which is two feet long, abounds in Java, with many other varieties of bats, both herbivorous and carnivorous. Two species of pangolin, or ant-eater, also belong to the archipelago.

*Birds* of the most brilliant plumage adorn the vast forests, including many families which, in temperate climates, are clad in sober hues. This is the home of the great green parrot, so easily taught to speak, with a host of kindred species of every color; of the peacock, and of the beautiful gold and silver pheasants. From here, also, our common domestic fowls are derived.

The crocodile and other *reptiles* frequent the rivers, venomous snakes being especially numerous; and insects of large size and brilliant tints abound.

3. EUROPE, which forms the peninsular headland of the great double continent, has no family or order of animals peculiarly its own; and a large number of its species are found in Asia or North America. Western Asia, Europe, and the Mediterranean region of Africa, so closely united, form but one zoölogical province, the principal types of animals, as of plants, being nearly identical.

The European reindeer, goat, fallow-deer, red deer, swine and cat, have all been domesticated; and it is possible that the moufflon of Corsica, and the wild cattle of Britain, may be the parents of the indispensable domestic sheep and kine.

## VIII.—ANIMALS OF THE SOUTHERN CONTINENTS.

### I. Africa.

1. GENERAL CHARACTER. The mammalia, the highest division of the animal kingdom, are ***especially characteristic*** of Africa, the highest orders occurring in greater numbers, both of species and of individuals, than in any other continent. More than two-thirds of the species inhabiting this continent are peculiar to it, though many are represented by kindred species in tropical Asia.

CHARACTERISTIC ANIMALS OF AFRICA.

Since so large a part of Africa is either utterly barren, or covered by temporary vegetation and watered by streams that flow only during the rainy season, fleet animals, fitted to live on arid plains, and the carnivorous animals, which prey upon them, are particularly numerous. The most bulky species of the land animals also abound in equatorial Africa, especially in the lake regions and in the neighborhood of the coasts.

2. The ARID REGIONS of southern Africa and the borders of the Sahara, which during the rainy season have a rich and varied vegetation, are inhabited by immense herds of antelopes, of almost innumerable species, among which the eland is the largest, and the gnu the most peculiar; by the zebra, and its kindred the quagga—animals of the horse kind; together with lions, leopards, panthers, and other beasts of prey, everywhere numerous. The ostrich also abounds in the arid plains both of Northern and of Southern Africa.

3. EQUATORIAL AFRICA. *Principal Mammals.* This portion of Africa is the home of species of the elephant and rhinoceros differing from those in Asia; of the hippopotamus, peculiar to Africa; and of the wild boar.

The giraffe, or camelopard, the largest of the ruminants, also peculiar to Africa, is found everywhere south of the Sahara; together with several varieties of oxen and buffaloes, sheep and goats.

The chimpanzee and the gorilla, kindred to the orang-outang, inhabit the forests of the western coasts; with apes and monkeys of many species, and large bats in great numbers.

*Birds* in great variety abound, there being no less than 59 species of birds of prey in this continent. Kingfishers and swallows, the most brilliantly colored of their kinds; and guinea-fowls in immense flocks, frequent the margins of the lakes and streams.

Web-footed birds and waders are also numerous. Among these are the beautiful Numidian crane, the ibis, the sacred bird of the ancient Egyptians, and the flamingo.

Honey-birds, the representatives of the American humming-birds, abound in South Africa, where the many flowering plants supply them with food.

The crocodile and other *reptiles* inhabit the marshes and the borders of the lakes and streams; and tree serpents, also, are numerous. Among the latter is the python, the Old World kindred of the American boa-constrictor.

### II. South America.

1. GENERAL CHARACTER. South America, with its wealth of moisture and its luxuriant vegetation, is distinguished by animals quite unlike the predominant species of Africa.

Those which give the peculiar character of the animal world in South America, are such as, by their mode of life, are connected most closely with the vegetable kingdom and the watery element.

The *insect world* is nowhere more rich, varied, and beautiful. The variety of species is almost inexhaustible, while in brilliancy of coloring and size of the body they are unsurpassed.

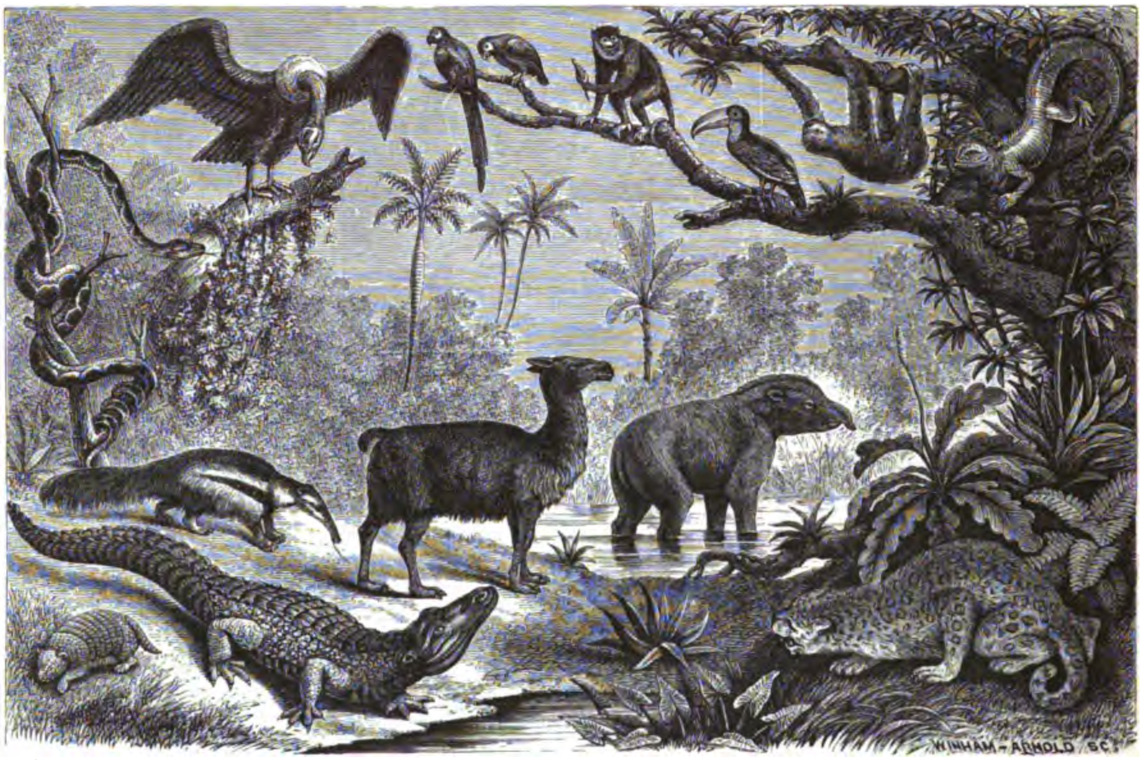
The *reptiles*, for which the many rivers, and the lagoons of the rainy season, furnish a most suitable abode, are especially numerous.

The alligator — the crocodile of the New World — multiplies in the warm, sluggish waters; and those gigantic lizards, the iguana and the basilisk, abound. The forests harbor serpents in immense numbers, and of almost every variety, including the monstrous boa-constrictor, the terror even of the native inhabitants.

2. CHARACTERISTIC BIRDS. The *most characteristic* birds are the stilt-plovers, inhabitants of the marshes and the shores, the species of which are more numerous in South America than in any other continent. Other waders and water-fowls without number are found here, including flamingoes, herons, ducks, and gulls. Of the humming-bird, which is confined to the New World, there are 150 species in South America, the continent of flowering forests, and but four in the whole of North America.

Among *other birds* peculiar to South America, are the toucan, with vivid colors and an enormous beak; and a number of species of long-tailed parrots, inferior in intelligence to those of India.

The condor, the largest of vultures, inhabits the Andes at 15,000 feet or more above the sea. The rhea, or American ostrich, lives on the treeless plains of the La Plata basin, and a bird of kindred species roams the high, arid plains of Patagonia.


WINHAM-ARNOLD SC.

Boa-Constrictor. Armadillo. Condor. Ant-Eater. Crocodile. Parrots. Llama. Monkey. Toucan. Tapir. Sloth. Jaguar. Iguana.

CHARACTERISTIC ANIMALS OF SOUTH AMERICA.

3. CHARACTERISTIC MAMMALS. Among the mammals, also, the *dominant types* are those of an inferior character. Opossums, a subdivision of the marsupials,[1] the lowest of the mammals in organization, are numerous, but none are much larger than a rat.

The order of edentata — including the armadillo, pangolin, ant-eater, and sloth — is especially characteristic of South America. This continent has twenty species of these animals, while but four species occur in Africa and Asia together.

4. HIGHER ORDERS. The South American representatives of the higher orders are smaller, less strong, and in every respect inferior to the corresponding animals of the Old World. Instead of the gigantic elephant, rhinoceros, and hippopotamus, and the fierce wild boar, South America has in this order only the feeble and harmless tapir, and the peccary.

In place of the camel and dromedary, antelopes, oxen, sheep, and other ruminating animals, — so numerous in Africa and tropical Asia, — South America has, besides a few deer, only the llama, alpaca, and vicuña of the Andes, and the guanaco of the plains. The llama, though allied to the camel, is scarce half its size, and has not a tithe of its strength or endurance.

The majestic lion, tiger, and leopard, are represented in South America by the puma, the ounce or jaguar, and the ocelot, which, though fierce and powerful, are much smaller than their Old World kindred.

The monkeys of South America, also, — with a prehensile tail, and a wide, flat nose, — are of a lower order than the tailless monkey of the Old World; while the apes, more resembling the human form, are entirely wanting in this continent.

### III. Australia.

1. GENERAL CHARACTER. The fauna of Australia differs from that of all other continents as greatly as does its flora. Its animals are not only few in species, and in numbers when compared with the extent of the continent, but are of a very unusual type. The majority are peculiar to this continent, and have not even kindred types elsewhere.

2. CHARACTERISTIC ANIMALS. Australia is especially characterized by the marsupials, which inhabit this continent in great numbers, and all of which, with the exception of the opossums, are confined to Australia and its islands.

The Australian marsupials include a large number of families, some of which are carnivorous, others herbivorous. Many resemble in their habits, and to a certain extent in appearance, animals of higher orders in other continents. The most numerous and characteristic, as well as the largest, are the kangaroos, of which there are nearly forty species.

The ornithorhynchus and the echidna (illustration, p. 111), are the most remarkable of Australian animals. The former, which is covered with fur, has a head, body, and legs similar to a quadruped, with the bill of a duck, and partially webbed feet. The latter, similar in organization, is covered with quills like a porcupine, is a burrowing animal, feeds on ants, and lies dormant during the winter.

3. HIGHER ORDERS. The large, noble, and powerful animals, so numerous in Africa, are entirely wanting in Australia, as are also the monkeys, so abundant in both of the other

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[1] Animals provided with a pouch for carrying their young, which are produced in a much less developed condition than the young of other mammals.

southern continents. There are no native ruminating animals, large or small; nor any beasts of prey larger than the wild dog, or dingo, and a carnivorous marsupial called the Tasmanian wolf.

4. The BIRDS of Australia are no less peculiar than the mammals. Among them are the beautiful lyre bird, and the birds of paradise; a large number of parrots and cockatoos, unlike those of the other continents; the emu and the cassowary, birds of the ostrich kind, which inhabit the arid plains of the interior; and apteryx, whose singular forms recall the birds of geological times.

## II. — PROVISION FOR HUMAN LIFE.

### I. — FOOD, RAIMENT, AND SHELTER.

### I. Introduction.

Man, even in the most primitive conditions of society, must provide himself with food, raiment, shelter from the elements, and implements with which to accomplish his designs. Nature furnishes him the materials for all these, which he employs, either in their crude state, or in modified forms which are the result of his own activity and skill. Of all the vast wealth of nature, however, whether in the vegetable, the animal, or the mineral kingdom, comparatively few things are directly useful in supplying the wants, or contributing to the progress, of the human family.

WINKHAM-ARNOLD Sc.
Cockatoo.
Bird of Paradise.
Bandicoot.
Apteryx.
Lyre Bird.
Kangaroo.
Kangaroo Rat.
Wild Dog.
Echidna.
Ornithorhynchus.
Emu.
Banded Ant-eater.
Black Swan.

CHARACTERISTIC ANIMALS OF AUSTRALIA.

### II. Sustenance.

1. EXTENT OF SUPPLY. Food sufficient for the support of life, either from the vegetable or the animal kingdom, is found in all climes, for all are inhabited. The materials employed, however, vary with the climate.

2. IN THE TROPICAL ZONE the *diet of the native man* is almost exclusively vegetable; and is obtained from plants growing spontaneously, and furnishing a constant supply of food in all seasons of the year.

*Chief among these* are the bread-fruit tree (Artocarpus), and kindred species; the banana (Musa), the manioc (Jatropha manihot), the arum or taro (Colocasia), the yams (Dioscorea), and the palms.

3. IN THE TEMPERATE ZONE, a considerable proportion of *the food consists* of animal substances, and the food-plants require cultivation to make them available to any extent.

The *native fruits*, *grains*, and *edible roots*, or root-stocks, are, in their wild condition, of little value for purposes of nutrition, and are confined to limited areas; while the long dormant season of winter cuts off all supplies for a part of the year. Hence in this zone, where nature furnishes, so to speak, only the germs of food-plants, man is obliged constantly to supplement her work by forethought and intelligent labor.

The *animal food*, in the Old World, has been from time immemorial derived chiefly from domesticated animals; while the native man of the New World seems to have always depended on the wild animals of the chase, few tribes having risen above the condition of hunters.

4. IN THE FRIGID ZONE, food-plants are almost entirely wanting. The sustenance of the native man is chiefly, if not wholly, animal; and is derived to a great extent from the inhabitants of the sea.

5. FOOD PLANTS OF CIVILIZED NATIONS. The main *sources of the vegetable food* of civilized nations are the *cereals*, — including wheat, rye, oats, barley, maize, millet or durrah, and rice; the different varieties of *pulse*,—as peas, beans, and lentils; a few plants yielding esculent *tubers*, *bulbs*, *roots*, or *leaves*, — as the potato, sweet potato, onion, beet, carrot, and cabbage; the *cucumber* family, as the melon, squash, etc.; and a few *succulent fruits*, chiefly of the apple, pear, peach, plum, grape, and citron families.

Millet forms the chief bread-corn of Africa, and is commonly used in tropical Asia also; but rice probably furnishes sustenance to a larger proportion of the human family than any other single plant, being in constant use, as the chief article of diet, in India, China, and Japan. The other cereals, with the exception of maize, do not thrive within the tropics, except on the elevated lands.

The *date* replaces bread to a great extent among the inhabitants of the arid regions of northern Africa and western Asia, where it is cultivated in the oases.

### III. Luxuries.

1. ARTICLES OF LUXURY. There are other articles which, though not essential to the sustenance of the body, — some being even highly injurious, — are, nevertheless, in constant use among the different peoples of the earth. These may be distinguished as *luxuries*.

*This class includes* sugar, and the spices, which are used as condiments; tea, coffee, and chocolate, employed as accompaniments to solid food; a variety of stimulating beverages; and narcotics, especially tobacco, opium, and hashish which is extracted from the common hemp, and is said to surpass opium in its intoxicating effects.

*Of the narcotics*, only the first named is used to any extent in Europe and America; the second replaces it in eastern Asia; while in western Asia, especially among the Turks, all three are habitually employed. *Perfumes* in great variety are also in constant use, both among European and Oriental nations.

2. COMMERCIAL IMPORTANCE. These, and other articles of luxury, the production of which is confined to the tropical zone, or to limited areas in temperate latitudes, enter largely into the commerce of the nations of Europe and America. Thus they furnish occasion for that constant intercourse of the latter with the less advanced peoples of Asia and the barbarous races of the tropics, by which the benefits of civilization are extending throughout the world. The luxuries of life—"spicery, balm, and myrrh"—were also among the earliest known articles of commerce. (See *Metals*, below.)

## IV. Materials for Raiment.

TEXTILE MATERIALS, from either the vegetable or the animal kingdom, abound throughout the tropical and temperate zones. Those chiefly in use are *wool*, from the sheep and goat of the northern temperate zone, and the alpaca of the southern; *flax*, the product of the northern temperate; and *silk* and *cotton*, of the warm-temperate and the tropical. In the cold zones these articles are replaced to a great extent by the furs and skins of the wild animals.

The *common hemp* (*Cannabis*), a plant closely allied to the nettle, yields a remarkably tough fibre, capable of being manufactured into linen and cordage. The leaf of the *pineapple* (*Anana*) furnishes the material from which a delicate transparent tissue, known as pina-cloth, is woven. The leaf of the so-called *New Zealand flax* (*Phormium*), a plant of the lily family, affords a strong fibre similar to flax, and was in use among the native inhabitants of New Zealand at the discovery of their island by Europeans. A considerable number of other plants, especially within the tropics, furnish fibres suitable for the manufacture of coarse cloth or cordage, and are in use among the native peoples.

## V. Materials of Construction.

*Timber* suitable for the construction of buildings, ships, or vehicles for land transportation, and the furniture and implements of common life, abounds in all of the zones; but the superior hardness, rich color, and fine grain of many woods of the tropical zone, fit them especially for the construction of those articles in which elegance as well as durability is sought.

The *rocks of the earth*,—granite, sandstone, marble, etc.,—everywhere near the surface except in alluvial plains, form an almost imperishable building material; and, where these and timber are wanting, clay, moulded into brick, serves the same purpose. In the frozen zone, among the Esquimaux, even blocks of snow serve to construct comfortable abodes.

## II.—MINERALS EMPLOYED IN THE ARTS.

### I. Distributions in the Continents.

*North America*, in the eastern half, is characterized especially by the useful minerals, coal, iron, copper, and lead. The workable coal-fields of North America exceed in extent those of all other countries taken together. The precious metals abound in the West—gold especially in the Sierra Nevada Mountains, silver in the plateaus of Mexico and the United States, and both in the Rocky Mountains. Mercury, essential in gold and silver mining, also abounds in California.

*Europe* is characterized by an abundance and wide diffusion of nearly all of the useful minerals. The precious metals occur in many places, but, except in the Ural Mountains, and the Little Carpathians, they are found only in comparatively limited quantities. Diamonds are found in the Urals, other gems are numerous in Spain and Transylvania; and the most beautiful marbles abound in the southern peninsulas.

*Asia*, like Europe, is distinguished by the variety of its valuable minerals. The precious metals are found in greater abundance than in Europe, especially in China, the Altai Mountains, and India; also in the Archipelago, where they are associated with diamonds. The diamonds of Golconda, in India, were famous in ancient times, but they are now nearly exhausted. Rubies and other gems are found in India, in Mongolia, and elsewhere.

*South America* possesses inexhaustible supplies of both precious and useful metals, especially in the Andes, where copper and silver are particularly abundant. Diamonds abound in Brazil, in the neighborhood of its central water-shed, where gold is also found.

In *Africa*, so far as known, iron, copper, and gold are the most widely diffused of the metals; but our knowledge of the mineral wealth of this vast continent is very imperfect. Rich diamond fields have recently been discovered in the basin of the Orange River.

*Australia* is characterized by the great abundance of gold in the southeastern part, and the inexhaustible supplies of the finest copper in the south. Silver, mercury, lead, zinc, and iron also are found in workable quantities. Thus the poverty of the vegetable and the animal world in this continent is compensated by its mineral wealth.

*Iron*, *coal*, and *salt*, the most indispensable of minerals, are more widely diffused than any other. No continent is deprived of them, and few countries lack an abundant supply.

*Salt*, the only substance used as food which is taken directly from the mineral kingdom, is obtained by evaporation from springs, salt lakes, and sea-water; and also occurs in beds of crystalline or rock salt.

The most famous of *salt mines* is that at Wieliczka, near Cracow, in the Austrian Empire. This mine, which has been worked since the middle of the thirteenth century, and seems inexhaustible, forms a veritable underground city, where people pass their entire lives without seeing the light of the sun. Our own country contains several rich salt-beds. Chief among them is the Muddy Salt Mine in southern Nevada, a bed of pure, transparent, crystalline salt, with an area of two square miles or more, and an unknown depth. Another, containing 146 acres, occurs in an island of the Gulf of Mexico, near the mouth of Atchafalaya Bayou.

The DISTRIBUTION of coal, diamonds, and the useful and precious metals, is indicated on the accompanying map. Each has its special sign and the comparative amount which occurs in any given region is indicated by the size of the sign.

### II. The Principal Metals.

1. NATURAL CONDITIONS. Iron, lead, tin, mercury, and zinc, in workable quantities, occur only in the form of ores. Copper and silver occur as ores, and also in the metallic state. Native, or metallic, copper is found in every continent, and, though much less abundant, is almost as widely diffused as iron.

Gold and platinum occur only in the metallic state, either pure, or alloyed with silver or other rare metals. They are found both in mines, and also among the sand and gravel in river beds, or alluvial formations called placers, where the *débris* of metalliferous rocks have been deposited.

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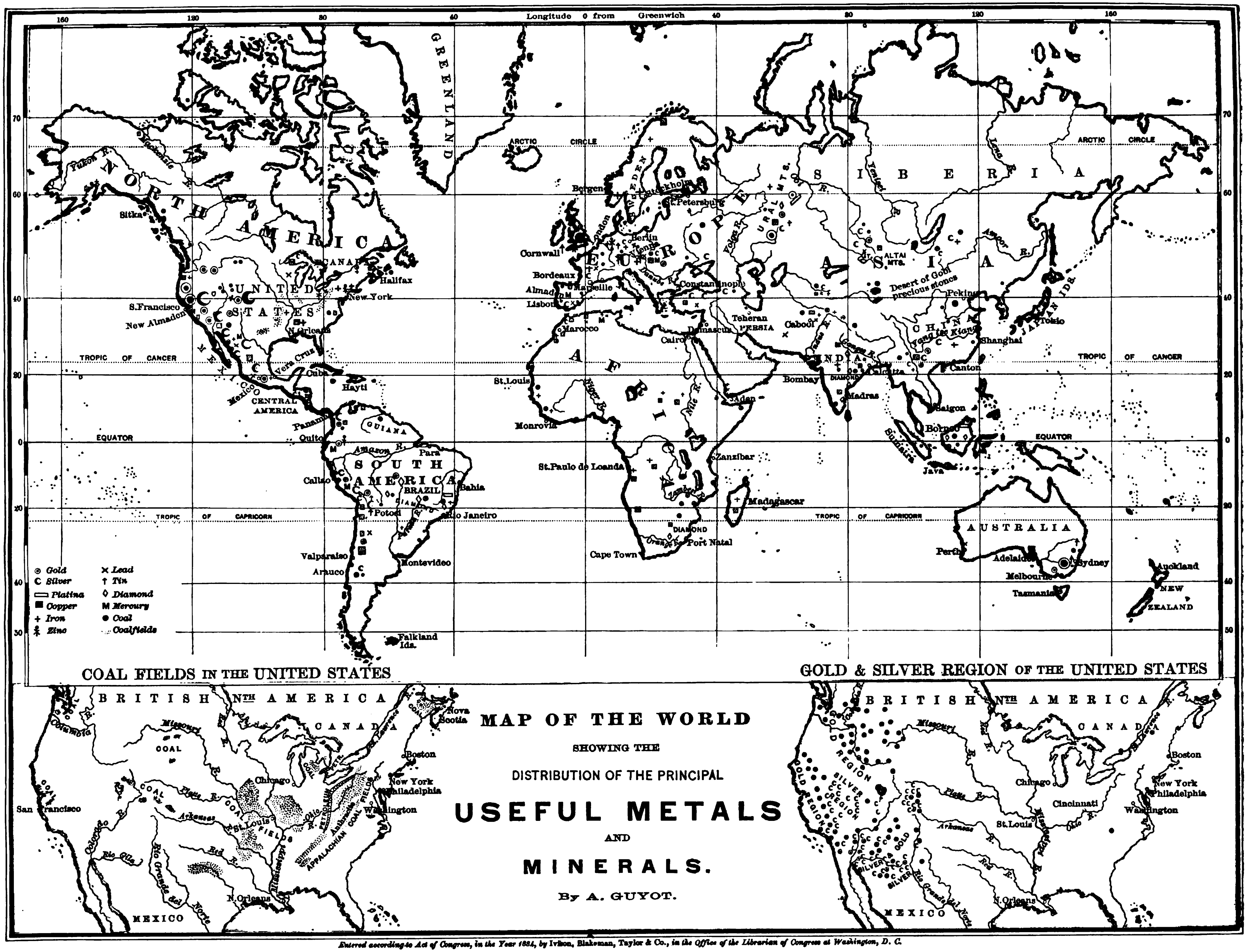
## QUESTIONS ON THE MAP OF MINERALS.

In what two regions of the globe is gold most abundant?
In what three regions in Asia-Europe is it found in the largest quantities?
In what two continents is the largest quantity of silver?
In what two regions in Asia-Europe is silver most abundant?
In what parts of Europe are the richest iron mines? In what parts of North America?
What metals, besides silver and copper, occur in the northern half of the Andes? In the central and southern Andes?
What metals, besides silver, abound in Central America and Mexico?
What minerals are found in the British Isles? In Japan? In Borneo? In China? In India? In the Altai Mountains? In the Urals? In Central Europe? In France and Spain? In Southern Africa? In New Zealand?
Name all the regions in which diamonds are plentiful.
What minerals abound in the United States east of the Mississippi?
What minerals abound in the region included between the Ohio, the upper Mississippi, and Lake Superior?
What minerals, besides gold, near our Pacific seaboard?
What, besides silver, in our great plateaus? What, besides gold and silver, in our portion of the Rocky Mountains?
Where are our richest deposits of iron? Of lead? Zinc? Copper? Mercury?
Where (see small map) are the greatest coal-fields of the United States?
Where are the principal petroleum regions?
Where are our three main gold-fields?
Where is our principal silver region?
In what regions east of the Mississippi is gold found?



# MAP OF THE WORLD

SHOWING THE

DISTRIBUTION OF THE PRINCIPAL

# USEFUL METALS

AND

# MINERALS.

By A. GUYOT.

*Entered according to Act of Congress, in the Year 1884, by Ivison, Blakeman, Taylor & Co., in the Office of the Librarian of Congress at Washington, D. C.*

2. Antiquity of Use. *Copper*, which abounds as a native metal, *tin*, used to alloy it, and *gold* and *silver*, were in use in western Asia in the most remote antiquity, the first two being the earliest employed in the arts of life. Weapons, ornaments, vases, and other works of art, in pure copper, or in bronze formed by alloying copper with ten per cent of tin, are found among the remains of prehistoric ages, where articles in other metals, of equal antiquity, are entirely wanting. *Lead* and *iron* were, however, in use in the earliest historic times.

Weapons and cutting implements of stone, either rough or polished, seem to have preceded the use of metals everywhere except in Iran, Syria, and Egypt, where there are no indications of a period in which metals were unknown.

*Zinc* replaces tin in some of the antique bronzes, but it seems to have been procured in the reduction of copper ores, with which it often occurs. No zinc mines were known until near the Christian era. *Mercury*, indispensable to modern civilization, and *platinum*, invaluable to the chemist, were unknown to the ancients.

3. Ancient Mines. The following were the chief sources whence the ancients were supplied with the metals: —

*Copper* — Nubia, and the Sinai peninsula; northern Syria, Armenia, and eastern Asia Minor (Pontus); the island of Cyprus; Greece, Italy, and Spain.

*Tin* — The Hindoo Koosh, and the southern Caucasus, — apparently little worked; Spain, the peninsula of Cornwall in England, and the adjacent Scilly Islands. The western mines alone supplied the merchants of ancient Sidon, Tyre, Phœnicia, and Egypt with this metal, which they transported even into India. Tin, from its rarity and importance, was a most precious metal of the early ages.

*Silver and Gold* — The Caucasus, Armenia, Pontus, northern Syria, and India; Nubia and south-eastern Africa; Spain and the Pyrenees.

*Lead* — Nubia, Asia Minor, the Island of Sardinia, Spain, and England. *Zinc* — Asia Minor. *Iron* — Nubia, Armenia, the Caucasus, Pontus, Syria, and Cyprus.

4. Ancient Commerce. The metals, gems from Spain and India, and amber from the shores of the Baltic, with spices and perfumes, were the earliest known objects of commerce. All the routes of ancient trade, and consequently of the spread of civilization from its earliest seats in western Asia and Egypt, were governed by the distribution of these articles.

## II. — THE HUMAN FAMILY.

### I. — RACES OF MEN.

#### I. Introduction.

1. Extent of Dispersion of Mankind. Man, unlike the individual species of animals or of plants, is confined to no climate, to no fixed assemblage of physical conditions. Though the greater portion of the human family inhabit the temperate latitudes, yet man is found in every zone; adapting himself alike to the burning heat and continuous summer of the tropics, and the intense cold and almost unbroken winter of the polar regions. All climes furnish him materials for food, raiment, and shelter, suited to his needs in the circumstances which surround him.

2. Diversity. Under the influence of ever-varying external conditions, the human family, — while preserving in all climes, and under all circumstances, certain common features of body and mind, which mark them as one, — display an almost unlimited diversity of physical and mental qualities, and of social conditions.

TYPICAL MAN.

1. APOLLO BELVEDERE. 2.

3. MONGOLIC. 4. WHITE. 5. AFRICAN.

6. AMERICAN. 7. MALAY. 8. AUSTRALIAN.

THE RACES OF MEN.

The *form* and *features* show every gradation, from the symmetry, grace, and dignity of the ideal man, portrayed by the sculptors of ancient Greece, to the ugliness and deformity of the Hottentot and the Fuegian. The *color* of the skin varies from white tinted with rose, through brownish or yellowish hues, to an almost jet black.

The *temperament* is here ardent and impulsive, the emotions responding with the vivacity of childhood to every impression, whether joyous or sad; there it is cold, passive, as in old age, almost insensible alike to pain or pleasure.

The *social condition* varies from the refinement and culture of the European nations, to the degradation of the savage who roams the tropical forests, or burrows in the earth in the Arctic islands.

3. Races of Men. Notwithstanding this almost infinite diversity in the human family, certain physical features and mental characteristics, which have remained unchanged from a time anterior to all history, are common to great groups of men. These different groups, however, are not so sharply defined that they can be regarded as specifically different; hence they are denominated *races*, instead of species, like the distinct groups of the animal kingdom.

The *number of races* recognized by different ethnologists varies according to the number of common features which each regards as essential to constitute a distinct type. Those usually taken into account are the stature and proportions of the body; the form of the head and of the features; the color of the skin, and the appearance and relative abundance of the hair and beard.

The races *are often designated* by the color, the most obvious distinction, though far from being a fundamental or a constant one; as the *white* race, the *yellow* race, the *black*, the *red*, etc.

#### II. The Geographical Races.

1. Number. From a geographical point of view, six distinct races are recognizable, each connected with one of the great geographical regions of the earth. Each shows, throughout all its branches, a common type, coinciding in all essential features with one of the types recognized as distinct by the most careful ethnologists.

2. Location and Name. The geographical races are as follows: —

(1) The *Central*, or *White* race, occupying western Asia and India, Europe, and the Mediterranean region of Africa, — the heart and centre of the great mass of the Old World.

(2) The *Mongolic*, or *Yellow* race, occupying the whole of eastern Asia, exclusive of India.

(3) The *African*, or *Negro* race (from the Latin *niger*, black), occupying all of Africa south of the Sahara.

(4) The *Australian*, a *Black* race, occupying Australia and its islands.

(5) The *Malayan*, or *Brown* race, occupying the Malay Peninsula, the Indian Archipelago, and the islands of the Pacific and Indian Oceans; extending from Madagascar to the easternmost limits of Polynesia, and from the Sandwich Islands southward to New Zealand.

(6) The *American*, or *Copper-colored* race, occupying the entire New World, exclusive of the Arctic shores and islands.

It will be observed that three of these races people the three connected continents which form the great, compact mass of the Old World, — one in the centre, one at the north and east, and one at the southwest. Two others people the remote continents, the Americas and Australia, while one is insular.

9. ABYSSINIA.

10. UPPER NUBIA.

11. WEST SOUDAN.

12. MOZAMBIQUE.

13. CAPE OF GOOD HOPE.

14. SOUTH DECCAN.

15. INDO-CHINA.

16. CELEBES.

17. FEEJEE ISLANDS.

18. SOUTH AUSTRALIA.

MODIFICATION OF TYPES.

3. CHARACTERISTICS. (1) The *White race* are distinguished by their tall stature, graceful proportions, and light, elastic step; their oval head and face, high broad forehead, symmetrical features, and ruddy cheeks; their abundant beard, and waving or slightly curling hair. The color of the skin varies with the climate, from white in the European, to tawny or swarthy in the Hindoos, Arabs, Egyptians, and Berbers, who live on the borders of the tropical zone.

This is frequently denominated the *Caucasian race*, the type being found in its greatest beauty in the Caucasus and the mountain lands of Iran, especially in Armenia and Persia. (Portrait 4.)

(2) The *Mongolic peoples* are characterized by their short stature; their broad form and high shoulders; their round head, narrowing at the top, and wide, flat face; their small chin, and prominent cheek bones, which give the face a triangular outline; their small, deep-set, oblique eyes; their coarse, straight hair, and scanty beard; and the yellowish color of their skin. (See portraits 3, 19, 20, 21.) This type is found most clearly marked in the people of the great plateau of Mongolia.

(3) In the *African* race, the stature is usually of average height, but the figure is often ungainly, the hands and feet large and flat, and the gait awkward. The head is narrow, and elongated backward; the forehead is low and retreating; the nose broad and flat, the cheek bones very prominent, the jaws projecting, and the lips thick; and the hair short and crisp, or woolly. (See portraits, 5, 11, 12.)

(4) The *Australians* show a general resemblance to the negro race, yet the form is still less symmetrical, often gaunt and meagre; and the features more irregular. The color is a livid grayish black; the hair thick and waving, or bushy; the beard abundant, and the eyes very deep-set, black, and piercing. (See portrait 8.)

(5) The *Malayan* race have, in general, the features of the Mongolic, with the lips somewhat thicker (portraits 7, 16), the eyes horizontal, and the hair less straight. The color is brown, varying in different tribes from nearly white to yellowish or blackish, according to their proximity to one or another of the neighboring races.

(6) The *American* race, also, show a remarkable resemblance to the Mongolic. The head, however, is less round; the forehead is narrower, the face less flat, and the jaws broader (portraits 6, 24); the eyes are horizontal, and the skin is reddish or copper-colored.

4. TYPES CLASSIFIED. The White, the Mongolic, and the Negro race, not only occupy the three connected continents which form the great mass of the Old World, but are much more clearly defined than the other types, the latter seeming to be scarcely more than modifications of the former. They may, therefore, properly be distinguished as the *primary races*.

The American, the Malayan, and the Australian race, less strongly marked than the others, may be designated the *secondary races*. Of these the first two resemble the Mongolic rather than either of the other primary races, and may be distinguished as the *Mongoloid* types. The Australian is *Negroid*, with scarce a feature similar to either the White or the Yellow race.

### III. The White Race the Normal, or Typical, Race.

1. The TYPICAL MAN — as exhibited in the unrivalled works of the ancient sculptors (see the *Apollo Belvedere*, 1, 2) — is distinguished by perfect regularity of features, and harmony in all the proportions of the figure, securing agility and strength in the highest degree, with the utmost beauty and grace.

The *head* is oval, symmetrical, and well poised, its form showing the proper balance of all the faculties, with the just subordination of the lower to the

**higher. The *face* is a symmetrical oval, and is divided into three equal parts by the line of the eyes and the base of the nose. The *eyes* are large, well formed, and separated by a space equal to the length of the eye. The *mouth* is small and finely cut, the lips gracefully curving from the centre. The *stature* is tall, lithe, and graceful, the shoulders not disproportionately wide nor narrow; while the distance measured by the extended arms is equal to the entire height of the body.**

These ideal harmonies of proportion *are realized* in many individuals among the nations inhabiting the mountain lands of Iran, in western Asia, — that region which Revelation, the traditions of the nations, and the affinities of their languages, alike indicate as the cradle of the human race, whence the whole family of man dispersed by successive migrations, in prehistoric ages.

The *Europeans* and their *American descendants*, who form part of the same great branch of the white race, have, in general, less regularity of features and harmony of proportions than the Persians and Armenians; but the face has more animation, more life and expression; the beauty is less physical, more moral and intellectual.

19. TURAN.

20. MONGOLIA.

21. CHINA.

22. KAMCHATKA.

23. ARCTIC AMERICA.

24. UTAH.

25. NEW MEXICO.

26. EASTERN BRAZIL.

27. ANDES OF PERU.

28. TIERRA DEL FUEGO.

MODIFICATION OF TYPES.

***Deviations*** **from these harmonies of proportion are therefore to be regarded as variations from the normal, or ideal man, and in so far as they show the preponderance of the lower or physical elements of man over the higher, or intellectual and moral, they indicate a degradation of the type.**

2. Gradual Modifications of Types. In proportion as we depart from Iran, the geographical centre of the races, the regularity of features diminishes, and the harmony of proportions disappears. This gradual transition of type is clearly shown in the successive peoples met with in all directions from this centre.

Passing *southward* we first meet the Arab, belonging unquestionably to the white race, but his head is less symmetrical, while his complexion varies with the climate to tawny and even to black.

Next are the transition types of Abyssinia (portrait 9) and Nubia (10), with features still comparatively regular; but with a swarthy or black color, closely curling hair, and an increasing resemblance to the negro. The inhabitants of West Soudan (11), show the true negro type; yet, while the skin is black and the features coarse, the expression of the face still indicates a lively intelligence. The same general characteristics are shared by the tribes of equatorial Africa and of Mozambique (12); but in the more southerly regions are the Hottentots and the Bushmen, who are among the most degraded types of humanity.

*Passing southeastward*, beyond the tawny yet beautiful Hindoos, we meet in the Dravidas of South Deccan (14), and the Siamese of Indo-China (15), slight modifications of the true White and Mongolic types, which form a gradual transition to the more distant Malayan (16). The pure Malay type belongs to the peninsula and the continental islands; the oceanic Malays differ materially in the different parts of their wide domain.

A number of intermediate types connect the true Malay with the Papoos, or bushy heads (17) — extending from New Guinea to the Feejee islands — who, though black, still possess some advantages of form. Farther south, through the true Australian type (8), we come to the south Australians and Tasmanians (18), among the ugliest of mankind, with gaunt body, meagre members, bending knees, hump back, and projecting jaws.

Passing *northeastward* to the extremity of Asia we observe almost insensible transitions, through the Tartars (19) and other Turanian people (see Map) — some of whom are hardly distinguishable from the White race, — to the true Mongols of the plateau (20).

Beyond, the Chinese (21) are still true Mongolians, but the Japanese are less strongly marked. The Kamchadale (22) is clearly a transition type through which we reach the Esquimaux (23), of the Aleutian Islands, and the Arctic lands of America.

Passing *southward through America*, we meet, in the middle latitudes, the Indians of the Rocky Mountains (6, 24, 25), who are a comparatively noble type, often tall and symmetrical in form. In the tribes of South America (26, 27) we observe an increasing deformity and ugliness; while the Pecherays of Tierra del Fuego (28) are the most misshapen, the farthest from any culture, the most wretched of the inhabitants of the New World.

## QUESTIONS ON THE MAP OF THE RACES.

What branches of the Mongolic race people the eastern shores and islands of Asia?

What branches people the Arctic plains? What peoples intermediate between the latter and the Esquimaux of America?

Where are the true Mongols found? What branch of their race south of them?

What peoples are included in the Turanian family?

What Turanian peoples in Europe and Asia Minor?

Name the Asiatic branches of the Indo-European family; the European branches.

What part of Europe does each of these great branches occupy?

Name the Semitic peoples of northern Africa.

What are the three principal branches of the Malay race?

What portions of the New World are occupied by Indo-Europeans? Of Africa? Of Australia?

What are the eastern branches of the American race in North America? The western branches?

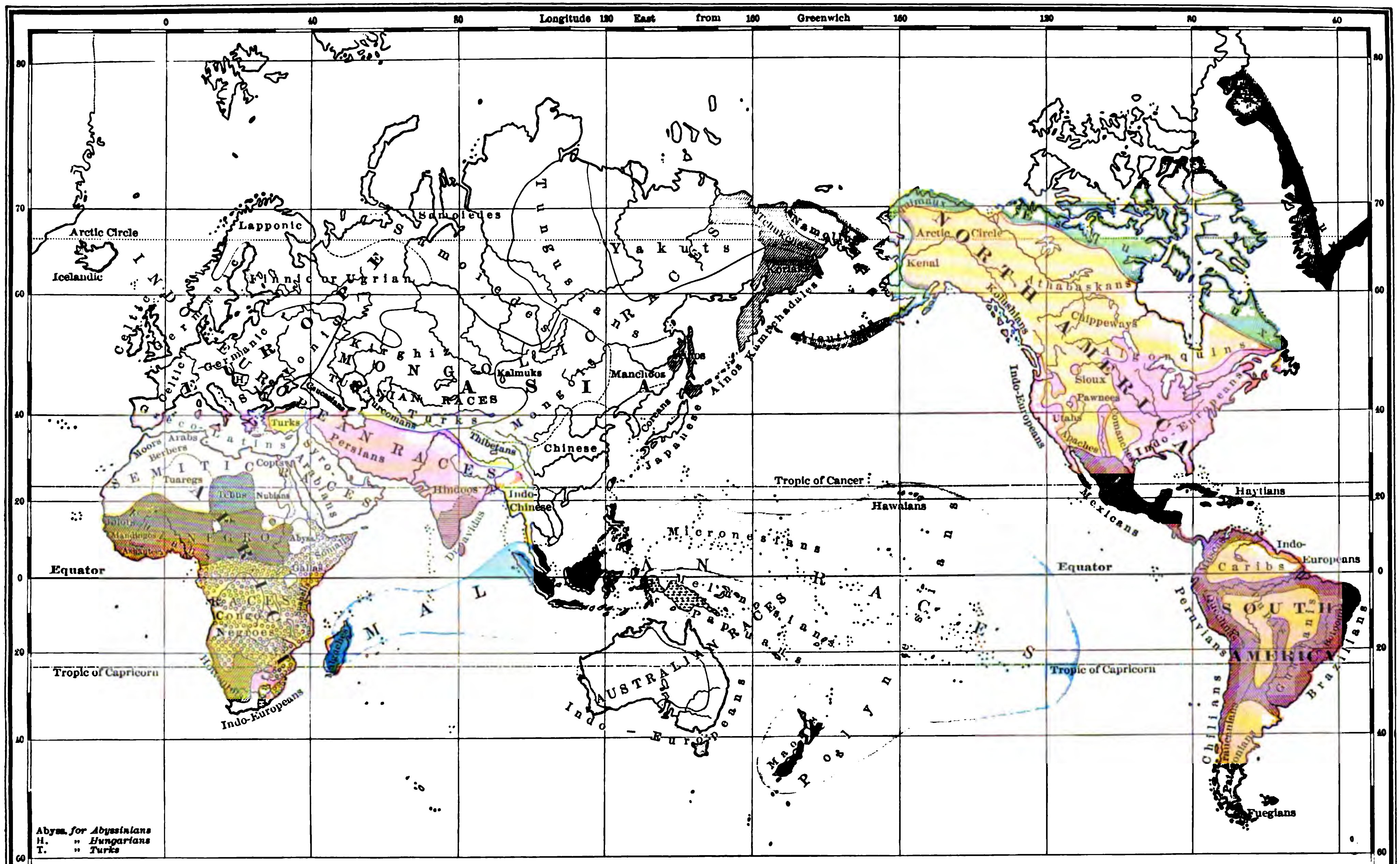
What are the principal branches of this race in South America?

What mixed races in South America and the southern part of North America?

What race intermediate between the Malays and the Australians?

What races in North Africa intermediate between the whites and the true negro?

What mixed races in eastern Africa? What part of Africa is peopled by Hottentots?



# DISTRIBUTION

OF THE PRINCIPAL

# RACES OF MAN

## UPON THE GLOBE.

By A. GUYOT.

GEOGRAPHICAL RACES.

Primary.

☐ Central or White Race.
☐ Mongolic or Yellow Race.
▨ African or Black Race.

Secondary.

■ Malay or Insular Race.
☐ American Race.
☐ Australian Race.

INTERMEDIATE AND MIXED RACES.

☐ Turanian.
☐ Finnic or Ugrian.
▨ Ainos, Kamchadales, &c.
▨ Dravidas.
☐ Africanised Semites.—Abyssinians, Berbers.
■ Tebus.
▨ Gallas, Somalis.
■ Hottentots.
▨ Papuans.
■ Spanish-Americans.
■ Portuguese Americans.
■ Esquimaux.

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## II.—UNITY AND CULTURE OF THE RACES.

### I. Unity of Mankind.

1. Evidences of Unity. A comparison of the different tribes and races of men, reveals the fact of a *gradual modification* of types, on every side of the central or highest race, until, by insensible degrees, the lowest and most degraded forms of humanity are reached.

Again: *in the central race*,—among the individuals of which there is greater diversity in form, features, temperament, and mental characteristics, than in any other,—there are persons of pure blood who show, in a less degree, almost every distinguishing feature of each of the lower races.

These facts establish a *bond of union* among all the varieties of mankind, however remote they may appear to be from the most noble type. They also seem to indicate that the White is the normal race, from which the others have gradually deviated.

2. The Law of Perfection of Type in man, therefore, forms an exception to that observed in the lower orders of creation. (Page 106, Topic I.) The human family appears in its *highest physical perfection*, not within the Tropics, but in the Temperate Zone, in western Asia, the geographical centre of the Old World.

The *type degenerates* gradually, with increasing distance, in all directions from this geographical centre; until, in the remotest regions of the globe, are found the ugliest, and the most deformed specimens of the human family.

The *degree of perfection of the type* is therefore proportioned, not to intensity of material agencies, but to distance from the central and highest race, irrespective of climatic conditions. The degree of culture of the races also varies in the same order. The central race is the race of culture and progress, both now and in all past ages.

### II. The White Race.

1. Branches. This race is divided, on the basis of language and mental characteristics, into three great branches, designated the *Hamitic*, *Semitic*, and *Japhetic*, or Indo-European, families, each of which has had its especial function in history.

The *Hamitic* family were the ancient people of Palestine, the Nile basin, and the shores of the Arabian Sea and Persian Gulf. They have either passed away or have so blended with their Semitic and Japhetic conquerors as to be scarcely distinguishable.

The *Semitic* family, who first appear on the upper Euphrates and in Syria, spread over the larger part of Arabia and, later, over northern Africa.

The *Indo-European* family, whose original seats appear to have been on the northern borders of Iran, spread over this entire table-land, and westward, through Europe; while a small branch went eastward into India.

2. Their Work. The Hamites and Semites were the earliest to gather into communities with organized governments, and to cutlivate the arts and learning.

The *Hamites*, a practical and inventive people, developed especially in the direction of material civilization; though they made comparatively high attainments in literature and in mathematical science.

The *Semites* were the guardians of the ancient revelations. Though contributing less than the Hamites to the material progress of the race, they gave to the world in succession the simple religion of the patriarchs, the Mosaic ritual, and Christianity, the fundamental principle of modern civilization. Later, Mohammedanism had its origin among the same people.

The *Indo-Europeans*, though later in entering upon their career, and deriving the germs of their civilization from the other two families, have shown themselves to be emphatically the people of progress.

The Greco-Latin branch, in southern Europe, carried the heathen civilization of antiquity to its highest perfection; and the Christian civilization of modern times finds its highest expression among the northern branches of the same family. They now possess the entire New World, the continent of Australia, and the great peninsula of India; and have established themselves in various parts of Africa and upon the islands of the sea. (See map.)

### III. Mongolic and Negro Races.

1. The Mongolic Race is *more numerous* than any other, and, including the various Mongoloid types, more widely dispersed than all others together. This race very anciently attained a comparatively high degree of *civilization*, and founded a powerful monarchy in China. They have, however, contributed little to the progress of mankind in general, owing to their isolation, their jealousy of foreign nations, and the policy of non-intercourse so rigidly observed by them even to the present time.

The Japanese, though less ancient as a nation than the Chinese, surpass them in culture; and are now entering upon a new era of progress in re-organizing their social system on the basis of modern ideas.

2. The Negro Race have, by themselves, made only the first steps in civilization, and the great mass are still in the savage state. Where they have been brought under the influence of cultured nations, however, they have shown themselves capable of a high degree of progress.

A colony of American negroes have successfully organized the Republic of Liberia, on the west coast of Africa, which gives promise of doing an important part in the work of Christianizing and civilizing this great and rich continent.

### IV. Secondary Races.

1. The Secondary Races have contributed nothing to the present condition of mankind; and none of the existing branches have taken more than the first steps in civilization, except under the influence of the White or Mongolic races.

2. Ancient American Civilization. The inhabitants of the table-lands of Mexico, and of the high plateaus of the Andes, had, at the discovery of America, populous and rich cities, organized governments and religious systems, and great skill in some of the arts, especially in the working of gold, silver, and bronze.

There are ruins of a still higher and more ancient civilization, both here and in the highlands of Central America; but of the origin of these cultured peoples nothing is known definitely. Certain peculiarities in their customs, and in the works of art found in their tombs and ruins, point to an Asiatic origin for the Peruvian, and a Semitic or Egyptian for the Mexican civilization.

## III.—CONCLUSION.

## I.—THE TERRESTRIAL CONTRASTS.

### I. Introduction.

The three grand contrasts observed in the arrangement of the land masses upon the globe (page 21), re-appear in the climates, through which they exert a marked influence upon the character and distribution of every order of life.

The continental and oceanic worlds present a contrast of geographical elements,—the land, and the water, the most general and fundamental of all. The contrast of the eastern and the western world is one of area and structure. The northern and the southern world show essentially a contrast of climate.

### II. Continental and Oceanic Worlds.

1. The Oceanic World, the world of uniformity, is also the world of inferiority. The life predominating by quantity is that of the sea,—vastly lower, both vegetable and animal, than that of the land. Australia and the oceanic islands, alike, lack all the higher types, whether of plants or of animals, and are peopled only by the lower races.

2. The Continental World, characterized by diversity in all its conditions, is the world of superiorty both in the realm of nature and that of man. It is, however, not in the heart of the continents that the highest development is found; but in the maritime zone, or zone of contact of the continental and oceanic worlds, along the coasts, and in the great continental islands.

3. The Maritime Zone. *Advantages.* Here the vigor of the continents, their variety of reliefs, soil, and temperature, is blended with the moisture of the seas; and the extremes of

the continental climate (page 73) are tempered, without being reduced to the sameness of the oceanic.

Here, too, the great highway of the seas permits that constant interchange, both of commodities and of ideas, which seems essential to the development of human society; yet which, in the heart of the continents, is more difficult, sometimes almost impossible.

*Life.* We have seen that the highest types of the animal world, and the most varied forms of the vegetable, with many of the most precious of vegetable productions, are found in the islands of the Indian archipelago, on the margin of the oceanic hemisphere.

In the same zone of contact, we find the highest civilizations of eastern Asia, — in Japan, China, and India; while the shores of the Mediterranean were the theatre of the most cultured nations of antiquity; as those of the Atlantic are the scenes of the highest development and activity at the present day.

### III. Old and New Worlds.

1. The New World, — narrow, elongated, isolated between two great oceans; with a preponderance in its structure of plains which are everywhere open to warm sea-winds, — is, in the main, *characterized* by medium temperatures, abundant moisture, and the greatest luxuriance and power of vegetable life.

In *its fauna* the lower types predominate; and the *native people* are essentially the men of the forest, a race of hunters, without domestic animals, and with only the rudiments of agriculture here and there.

2. The Old World, — vast, compact, composed of the largest two land masses (Asia-Europe and Africa), closely crowded together, from a large part of which the sea winds are almost excluded, — *is characterized* by the greatest extremes of temperature; and by a lack of moisture and poverty of vegetation over immense areas of the interior. It is the domain of the higher orders of animal life, especially of animals capable of domestication; and of the civilized and progressive races.

### IV. Northern and Southern Worlds.

1. The Southern Continents, — lying mainly in the tropical zone, where all the conditions that stimulate physical life are most powerful, and where, with few exceptions, man has remained at the bottom of the social scale, — may be designated the *continents* of *nature*. Each has its own especial character, wherein the influence of every distinguishing feature of the continent is seen.

In *South America*, — the tropical continent of the Western World, and especially the continent of plains, — all the characteristics of the New World are exhibited in an exaggerated degree. It is pre-eminently the realm of vegetable life, where we find the largest, the most dense, and the most varied forests, and the greatest development of foliage on the face of the earth.

*Africa*, — the tropical continent of the Eastern World, and the continent of plateaus, — has, in an extreme degree, the dry continental climate of the Old World. It is, above all, the realm of the nobler animals, of the mammalia, — the highest division of the animal world, — which, by their number, their variety, their size and strength, give the African fauna its distinctive character.

*Australia*, the only sub-tropical continent, and the most isolated, the smallest, and the least varied of all, is the only one which preserves to a great extent the ancient forms of plants and animals. Its isolation, size, and structure, as well as its fauna and flora, find their parallel in the other continents in the middle geological ages.

2. The Northern Continents, may properly be designated the *continents of history*. Less richly endowed with those elements which foster the life of nature, they possess all the conditions most favorable for the development and progress of the races inhabiting them; and each was apparently designed, from the beginning, for the performance of a peculiar part in the education of mankind.

## II. — THE CONTINENTS OF HISTORY.

### I. Asia.

1. Characteristics. Asia is the largest of the continents, the most central, the only one with which all the others are closely connected; and the one whose different physical regions show the strongest contrasts, and are separated by the greatest barriers.

It has the loftiest mountains, the highest and most extended plateaus, the greatest plains, and the most numerous river systems; with all climates, from the hottest to the coldest, from the dryest to the most moist. It has, also, a large number of useful plants, and of animals capable of domestication; together with an abundance of both the useful and the precious metals.

2. Its Function. This great and strongly marked continent is the *continent of origins*. The human family, its races and civilizations, and the systems of religion which rule the most enlightened nations, all had their beginning here.

By the great *diversity of its physical features* and climate, and the strong barriers isolating them one from another, Asia was admirably fitted to promote the formation of a diversity of races; while its close connection with the other continents facilitated their dispersion throughout the earth.

Its *alluvial plains*, with their well-defined boundaries of mountains or deserts, and their rich soil, — covered annually by overflowing rivers with a fruitful loam, and so easily tilled that a plough was scarcely needed, — seem to have been especially adapted to foster the progress of a race still in its infancy.

The abundance of their resources, developed by agriculture, allowed the congregation of great numbers of men upon the same area, and thus favored the formation of organized governments; while the conflict with the overflowing rivers, the necessity of irrigation, and the alternation of the seasons, incited forethought, and gave birth to the useful arts and the sciences of observation.

3. Centres of Culture. The four great alluvial plains of Asia, — those of China and of the Amoo Daria, in temperate regions; of the Euphrates and Tigris in the warm-temperate; and of the Indus and Ganges under the tropic, — with the Nile valley in Africa, were the theatres of the most ancient civilizations known to history or tradition.

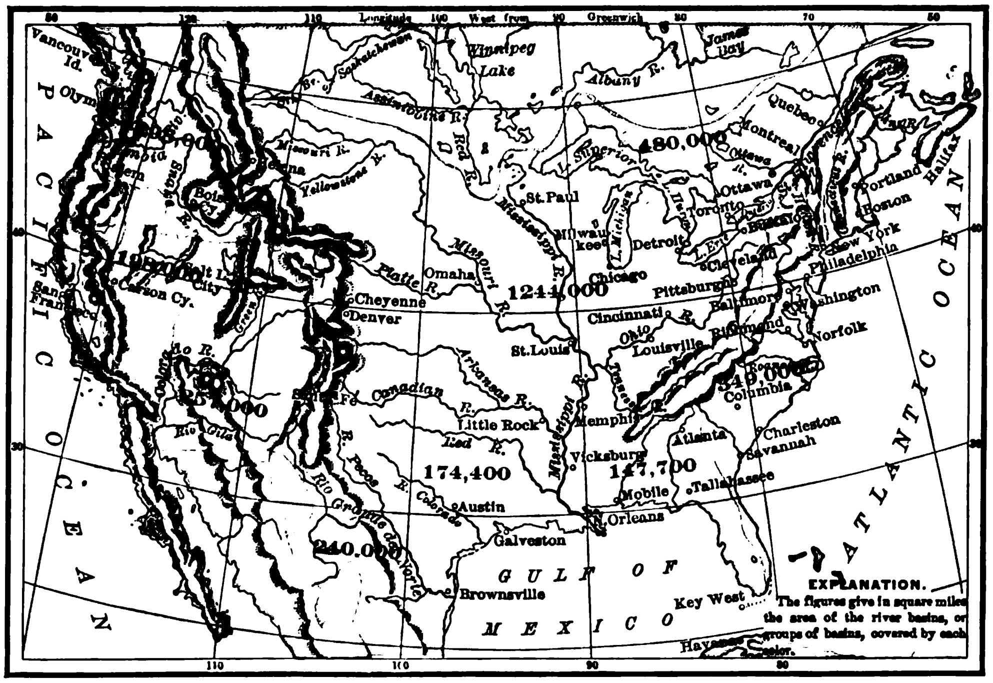
In the remotest antiquity each of these regions became the seat of a distinct nation, with a material and intellectual development, a religion, and a social organization peculiar to itself; and together they formed the five great centres of the primitive culture of the race.

China and India, isolated from each other, and from the West, by almost impassable mountains and desert plateaus, have left scarce a trace upon the subsequent progress of mankind; but the others, in greater proximity to Europe, became the parents of the higher culture of ancient Greece and Rome, and, through them, of modern civilization.

## II. Europe.

1. Characteristics. — Europe shows a *diversity of structure* even greater than that of Asia; but with smaller areas, more moderate forms of relief, less extreme contrasts of climate, a more generally fertile soil, and everywhere an abundance of the most useful minerals; while the relative extent of its coast line — its maritime zone — is greater than that of any other continent.

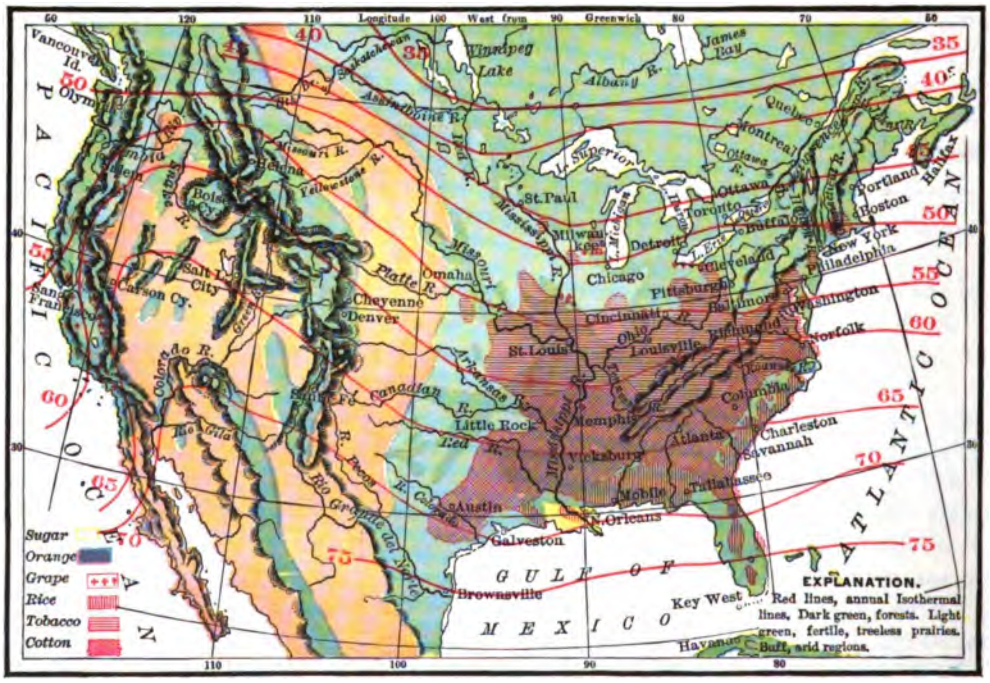
This continent is especially fitted, by its diversity, to foster the formation of distinct nationalities, each developing in an especial direction. Moreover, the proximity of these nations one to another, the greater facility of communication between them, and, above all, the common highway of the sea, nowhere very distant, facilitates mutual intercourse, the lack of which arrested the progress of the civilizations of Asia.



THE UNITED STATES. RIVER BASINS.

2. Centres of Progress. In Asia it is in the great inland plains, on the banks of the rivers, that civilization first shows itself. In Europe it is in the peninsulas and islands on the margins of the seas — the regions most accessible to influences from without — that the most ancient states are founded; for not only her inhabitants, but the germs of her culture, were derived from Asia.

3. Functions. Though not the continent of origins, Europe is emphatically the continent of development. The Indo-European *race* — the people of progress — find their fullest expansion and activity, not in their original seat in Iran, but in Europe, whence they are spreading over all quarters of the globe. The *arts* and *learning* of antiquity attained their highest development, not in western Asia and Egypt, the places of their origin, but in Greece and Rome. *Christianity*, also, only germinated in western Asia. Transplanted to Europe, it gradually attained its full development, and became the foundation on which is reared the vast and noble edifice of modern civilization.


Longitude West from Greenwich
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
35
40
50
55
60
65
70
75
Sugar
Orange
Grape
Rice
Tobacco
Cotton
EXPLANATION. Red lines, annual Isothermal lines. Dark green, forests. Light green, fertile, treeless prairies. Buff, arid regions.

THE UNITED STATES. VEGETATION.

## III. America.

1. Characteristics. America, different in position, structure, and climatic conditions, from both the other northern continents, seems destined to play a part in the history of mankind unlike that of Europe and Asia, though not less noble than either.

The *structure* of this continent (page 31) is characterized by a unity and simplicity as striking as is the diversity of Europe.

Few and vast physical regions — the western highlands and the eastern plains, the northern and the southern slope — with comparatively slight barriers between them, present a marked contrast to the multiplicity of areas, with clearly defined natural boundaries, which characterize Asia-Europe.

Again, great river systems, whose basins, narrowed to a mere doorway near the sea (see *Map of River Basins of U.S.*), spread wide in the interior, establish an easy communication almost everywhere between the east and the west, the north and the south.

In its *climate*, those contrasts in temperature which are so violent in Asia, and still prevail in Europe, are obliterated. The cold zone of the north passes by insensible degrees into the warm zone of the south; while in the western half the bracing climate of the temperate regions is prolonged into the tropical, by the greater elevation of the highlands towards the south.

The east and the west differ little in temperature, the elevation of the latter being counterbalanced by the exclusion of the polar winds, and the free sweep of the return trades over its surface.

Salt Lake City, for example, on the same parallel with New York, though more than 4,000 feet above it, has the same average annual temperature, which does not differ greatly from that of the corresponding latitude on the Pacific coast.

The *chief contrast of the continent* is that of the coasts and the interior, the maritime and the continental climates; but even this is softened, the great Gulf of Mexico carrying the maritime zone almost into the heart of the continent; while the warm equatorial wind spreads its wealth of vapors over the interior plains at the north and east. The high plateaus of the west alone are arid.

The *differences in surface* and *climate*, sufficient to create diversity in industries and in the products of the soil, are not, as in Asia, marked enough to give rise necessarily to entirely different modes of life among the inhabitants, and to create antagonistic interests. By fostering internal commerce, they unite rather than separate the people of the several regions.

Finally, the *oceanic position* of America secures its commercial prosperity, and prepares, at the same time, the means of its influence on the world.

2. THE MOST CHARACTERISTIC, as well as the most valuable, part of America, is the noble domain of the United States. Between the cold, semi-arctic northern slope, and the tropical climes of the south, it is situated wholly in temperate latitudes, with a climate the most favorable for the active life of civilized communities.

In the eastern half are fertile plains and valleys, teeming with agricultural wealth, or covered with forests; in the west, pasture-lands, or plateaus and mountains rich in silver and gold. On the north are corn-lands, water-power, and inexhaustible mines of coal, copper, and iron; on the south, tobacco, cotton, rice, and cane.

This *diversity of resources* creates the necessity for constant intercourse, which is facilitated to the utmost by the vast river systems, the great length of coast line, and the absence of barriers between the different regions. Thus the unity of the entire people is promoted, and the formation of local nationalities is checked.

Again, the *agricultural wealth* of the eastern half, flowing naturally to the Atlantic ports, is essential to the overcrowded industrial nations of western Europe; and brings the youthful and vigorous American people into constant contact with European culture, acquired through long ages of progress.

The *mineral treasures* of the Pacific slope, attracting a large and energetic population to that less fertile side of the continent, prepare the way for intercourse with the long dormant nations of eastern Asia; while from the ports of both oceans there is a ready access to the lower races in the continents of the south.

3. FUNCTIONS. Nowhere do we find in America those local centres, each having a strongly marked individuality, which fostered the progress of the race in its infancy and its youth; but everywhere provision is made for mutual intercourse, a common life, and the blending of the entire population into one. Evidently this continent was not designed to give birth and development to a new civilization; but to receive one ready-made, and to furnish to the cultivated race of the Old World the scene most worthy of their activity.

Its vast plains, overflowing with natural wealth, are turned towards Europe, and its largest rivers discharge into the Atlantic; while its lofty mountains, and less fertile lands, are removed far towards its western shores. Thus it seems to invite the Indo-European race, the people of progress, to new fields of action; to encourage their expansion throughout its entire territory, and their fusion into one nation; while it opens for them a pathway to all the nations of the earth.

America, therefore, with her cultured and progressive people, and her social organization, founded upon the principle of the equality and brotherhood of all mankind, seems destined to furnish the most complete expression of the Christian civilization; and to become the fountain of a new and higher life for all the races of men.

### IV. Conclusion.

Each continent has, therefore, a well-defined individuality, which fits it for an especial function. The fullness of *nature's life* is typified by Africa, with its superabundant wealth and power of animal life; South America, with its exuberance of vegetation; and Australia, with its antiquated forms of plants and animals.

In the grand drama of *man's life* and development, Asia, Europe, and America play distinct parts, for which each seems to have been admirably prepared.

Truly no blind force gave our Earth the forms so well adapted to perform these functions. The conclusion is irresistible — that the entire globe is a grand organism, every feature of which is the outgrowth of a definite plan of the all-wise Creator for the education of the human family, and the manifestation of his own glory.

## REVIEW OF PART V.

### Life in Nature.

**I.** (*Page* 97) How is the system of life in nature represented? What is the especial function of plants? Prepare an analysis of Section I.

**II.** What are the conditions of the development of vegetable life? Where is vegetable life possible with an average temperature below the freezing point? Why? (100) What is the mean temperature, and the characteristic vegetation, of the several zones? What useful plants belong to each? Prepare an analysis of Section II.

**III.** (101) How do the three northern continents compare in the character of their flora? What especially distinguishes North America from the others? What cultivated plants are derived from western Asia? Describe the flora of the Indian peninsulas and Archipelago. What is the characteristic vegetation of Arabia? Prepare an analysis of Section III.

**IV.** (102) What effect has increasing altitude upon vegetable life? Why? Describe the successive regions of plants upon the Himalaya Mountains. How does the flora near the snow-line on the Alps compare with that on the Andes? Why? Prepare an analysis of Section IV.

**V.** (104) Describe the flora of equatorial Africa; of northern Africa; of southern Africa. What are the characteristics of the South-American flora? To what are they due? Describe the tropical forests. What useful plants are indigenous in tropical America? (105) Why has Chili so much richer vegetation than the western slope of Bolivia and Peru? Prepare an analysis of Section V.

**VI.** (106) Explain the diagram which illustrates the aspects of nature. What is the general law of the development of life in nature? What are the characteristics of the tropical zone, in regard to both vegetable and animal life? Of the warm zone? Of the temperate zone? Of the cold zones? Prepare an analysis of Section VI.

**VII.** (108) What is the extent of the resemblance in the fauna of the northern continents? What animals are especially characteristic of North America? Of Asia? Prepare an analysis of Section VII.

**VIII.** (109) What is the general character of the African fauna? What animals are especially characteristic of the arid regions? Describe the fauna of equatorial Africa. What classes of animals are especially characteristic of South America? (110) What is the general character of the Australian fauna? What are the most characteristic animals? Prepare an analysis of Section VIII.

### Provision for Human Life.

**I.** (111) How do the materials employed as food vary in the different zones, and whence are they derived? To what extent are materials for raiment provided in nature? (112) What materials are provided for shelter, and the implements of life? Prepare an analysis of Section I.

**II.** What minerals characterize the different regions of North America? What is the nature and extent of the mineral wealth of Europe? Of Asia? Of South America? Of Africa? Of Australia? In what condition do the several important metals occur in nature? (114) Which metals were earliest brought into use? What reason can you suggest for the use of copper earlier than iron? What especial importance was attached to the distribution of the metals, and of some other articles, in remote antiquity? Prepare an analysis of Section II.

### The Human Family.

**I.** To what extent is the human family dispersed over the globe? In what zone are the larger proportion of mankind? On what basis is mankind divided into races? How many are the geographical races, and where are they located? (115) What are the characteristics of each of the primary races? What are the relations of the secondary races to the primary? What are the characteristics of the typical, or ideal, man? Where are these ideal proportions realized? (116) How are deviations from these proportions to be regarded? How does the type vary in departing from the geographical centre of the races? Describe the successive modifications towards the southwest; towards the southeast; towards the northeast; southward through America. Prepare an analysis of Section I.

**II.** (118) What are the evidences of unity in the human family? What is the law of the perfection of type in man? What and where are the three great branches of the White race? What has been the function of each in the gradual development of civilization? What is the condition of the Yellow race in regard to culture? Of the Negro? Of the secondary races? What remains of ancient civilization has America? Prepare an analysis of Section II.

### Conclusion.

**I.** What is the importance, and what the character of the three great terrestrial contrasts? What are the characteristics of the oceanic world? Of the continental? (119) What region of the continents appears most favorable to development? What are its advantages? Give examples of its superiority. What are the contrasting characteristics of the New World and the Old? Of the northern and the southern continents? What especial character has each of the continents of nature? Prepare an analysis of Section I.

**II.** What are the especial characteristics of Asia? What has been its function in the development of mankind? How is Asia adapted for that particular phase of human progress? What and where were the great centres of primitive civilization? (120) What are the especial characteristics of Europe? Where were the earliest seats of European civilization? Why in those regions? What is the historical function of Europe? Examples. (121) How is America characterized in structure? In climate? What is the nature and extent of these diversities? Describe the most characteristic portions of this continent. What appears to be the providential plan for America? What evident fitness does she show for this work? What conclusion is enforced by this study of the continents of history? Prepare an analysis of Section II.

*Note.*—In Part V. the analyses have been omitted in order to give the pupil an opportunity to analyze the several sections—an exercise for which he should now be fully prepared, and which will be of advantage to him. It would be well to require him to make a tabular analysis of each section as he proceeds with the study.

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## GENERAL REVIEW.

### Part I.

(*Page* 1) What are the geographical elements of the globe? (5) What advantages has the Earth over the other planets in its astronomical conditions? (6) What is the specific gravity of the globe? (7) What is the relation of longitude to time?

(8) What is magnetic declination, and how is it caused? (9) What is magnetic inclination? (10) Explain the formation of the geysers. (11) Explain the formation of artesian wells. (12) What is the average rate of increase of heat towards the interior of the Earth? Explain the formation of volcanic cones.

(15) What is the general distribution of volcanoes upon the globe? (16) What is the primary source of volcanic activity? Describe the different kinds of earthquake motion. (17) What is the condition of scientific knowledge in regard to the cause of earthquakes?

### Part II.

(21) What grand contrasts are observed in the position and grouping of the land masses?

(23) How do the several continents compare in the amount of articulation of their coasts? What (page 22) is the importance of these irregularities of outline? (24) Define the different classes of relief forms. (25) How do the different classes of plains vary in productiveness? (26) What is the importance of plateaus in the continental structures? What is the nature of the soil in most great plateaus? Examples. How are mountain chains formed? (27) What is the origin and classification of valleys among mountains? Describe the formation of valleys in plains and plateaus. Examples.

(30) What common features are apparent in all the continental structures? How are the general figure, and the individual contours of a continent determined? (31) How do the two continents of the New World compare in structure? What differences between the two highlands of South America and those of North America? What differences in the central regions of the two continents?

(33) What are the common features of structure in Asia and Europe? What are the especial characteristics of Asia? (35) What are the characteristics of the structure of Europe? (36) What peculiarity of structure in its central region? Describe the structure and surroundings of low Europe? (38) How does the structure of Europe differ from that of Asia? Describe the structure of Africa as a whole. (39) How does Australia resemble, and how differ from, Africa in structure?

(40) Repeat the first four general laws of relief. How is the fourth expressed in the structure of the several continents? (42) Repeat the remaining four laws. What is the dominant form of relief of the several continents? Explain the formation of the continental reliefs. (43) What is the distinctive character of the continental islands? Of the oceanic islands? Describe the formation of the coral reefs and islands. (45) What is the comparative value of the coral islands?

### Part III.

(48) Explain the formation of intermittent springs. Describe the erosive action of rivers in different parts of their course. (50) Explain the formation of deltas. (51) Explain the existence of salt lakes. Examples.

(52) Describe the geographical distribution of lakes. Describe and explain the general plan of drainage of North America. (54) Trace and explain the correspondence between the river systems of South America and those of North America. (55) Describe the general plan of drainage of Eastern Asia. What are the main hydrographical centres of Europe?

(57) Describe the general plan of drainage in Africa. Describe the Nile system, and explain its inundations. What are the peculiarities of the drainage of Australia? What general fact is brought to light by a study of the distribution of river systems?

(58) How does the surface temperature of the sea vary? (60) What are the greatest depths of the ocean? What are the comparative depths of the inland and border seas? (61) Describe the production of the tidal waves. (62) Explain the spring tides and neap tides. (64) What is the average height of the tide on the eastern coast of North America? (65) Describe the general circulation of the sea, with the cause. What are the directions of the polar and return currents? How is this direction explained? (67) Describe the climatic effects of the marine currents.

### Part IV.

(69) How is the pressure of the atmosphere measured? What is the effect of elevation on the density of the air? At what elevation is the pressure reduced one-half? (70) On what do the fundamental laws of climate depend? State and explain the general law of the distribution of temperature upon the globe. Explain the varying length of day and night, and the change of temperature in different seasons.

(72) In what do the general deviations from astronomical climates consist, and how are they caused? To what are local deviations due, and in what do they consist? (73) Explain the extreme contrasts in temperature, on the opposite coasts of the North Atlantic. How does the greater or less area of a land mass affect its temperature in the different zones? What are the characteristics of the continental climates? Of the oceanic? Explain the cause of this difference.

(76) Describe and explain the general circulation of the atmosphere. (77) Name the several wind zones, and give their positions. What is the cause (page 76) of the trade-winds, and to what is their direction due? What is the position and cause of the equatorial calms? (78) Explain the monsoons of the Indian Ocean. Explain the diurnal land and sea breezes. (79) What are the prevailing winds of the temperate zones? What is the direction of the return-trades, and what gives them (page 76) this direction? Whence do the polar winds start? What is their direction in Eastern Asia and North America? Why? Why are the polar winds less powerful in summer than in winter? What causes the frequent storms of spring and autumn? What causes a late spring or autumn? An early spring or autumn?

(82) What is the character of the storms known as hurricanes? (83) What are waterspouts? (84) On what does the capacity of the air for the absorption of vapor depend? (85) How do mountains affect the condensation of vapors? Examples. How do the nature and covering of the soil affect the condensation of vapor? (88) State the general law of the distribution of rain on the globe. The law of distribution of cloudiness and vapor.

(89) State the general cause, and the time, of rain in the different zones. Describe and explain the rainfall in the belt of calms; in the belt of trades. (90) What is the comparative amount of rain in the sub-tropical zones? Why is this? What is the cause of the winter rains, and where do they occur? What is the comparative amount of moisture in South America? Why is this? What is the especial character of Africa in regard to rain? Why is Northern Africa so dry? What is the comparative amount of rain in Australia as a whole? How do you explain the abundant rainfall in the eastern half of North America? Why are the high western plains and plateaus so dry? What is the comparative amount of rain in Europe?

(92) How does Asia compare with the other continents in the amount of rain it receives? Why is this? In what latitudes does snow fall at the level of the sea? (93) On what does the height of the snow line depend? Where is it greatest? (94) Describe the formation of a glacier. (95) What are icebergs? What is the supposed cause of the auroras?

### Part V.

(97) How is the system of life in nature represented? What is the function of the plant in the economy of nature? What are the climatic conditions of the development of vegetable life? What is the characteristic vegetation of each of the several zones? (102) How does vegetation vary at different altitudes? Why is this? Describe the vegetation of the Andes in the several vertical zones. What is the general character of the vegetable world in Africa? Why? (104) What are the especial characteristics of the vegetable world in South America? Why is this? What useful plants are indigenous in tropical America? (105) What is the general character of the Australian flora?

(106) What is the general law of the development of life in nature? Name the characteristic species of animals of tropical regions? (107) What are the characteristic animals of the temperate zone? What are the characteristic animals of the cold zones? (108) What are the especial characteristics of the animal world in North America? What orders of animals characterize Asia? (109) What is the general character of the animal world in Africa? What are the characteristics of the South American fauna? What divisions of the animal kingdom especially distinguish this continent? Describe the fauna of Australia.

(111) How does the sustenance of man vary in the different zones? In what zone are most of the food plants of civilized nations indigenous? From what zone are most of the luxuries derived? (112) What continents are especially characterized by the abundance of the precious metals? Which are distinguished by the abundance and variety of the useful metals? Which has the most extensive coal-fields? What metals were most anciently in use? What was the commercial importance of the metals in antiquity?

(114) What is the location and number of the geographical races? State the especial characteristics of each race. (115) Which approaches most nearly to the typical man? Where is this normal race found in its highest physical perfection? (116) What is the general law of the variation of types in man? Which race occupies the highest grade in intellectual culture and social condition? What are the three great families of the white race? What has been the especial work of each in the progress of civilization? What is the condition of the yellow race, and their relation to the general progress of mankind?

(118) What are the three great terrestrial contrasts? What contrasting characters are displayed by the life in the continental and the oceanic world? What is the region apparently most favorable to all development? What are its especial advantages for the development of life in nature? For human progress? What are the contrasting characteristics of the eastern and western worlds? Of the northern and southern worlds? What are the especial functions of the several southern continents? (119) What has been the historic function of Asia, and how was it adapted for this work? What has been the function of Europe, and how was it fitted for its work? What appears to be the providential design in regard to America? What characteristics indicate such a work for our continent?

# PRONUNCIATION OF NAMES EMPLOYED IN THE TEXT.

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EXPLANATION. ā, ē, ī, ō, ū, as in māte, mēte, mīte, mōte, mūte; ȧ, ê, ĵ, ô, u, a trifle shorter than ā, etc.; ă, ĕ, ĭ, ŏ, ŭ, as in măt, mĕt, ĭt, nŏt, ŭp; â, ê, î, ô, û, as in câre, thêre, fîrm, fôr, fûrl; ä, as in fär; a̤, as in fa̤ll; ȧ, as in lȧst; o̤, as in do̤; ȯ, as in dȯne; ṳ, as in rṳde; ụ, as in pụsh; ẽ, as in tẽrm; ạ, ẹ, ọ, as in fragrạnce, Salẹm, Hudsọn.
ḡ, as in ḡo; ñ, as in cañon (can′yon); ɴ, silent, indicating that the preceding vowel has a nasal utterance, as though pronounced with the nostrils closed (as in Toulon, tṳ-lôɴ, where the ô is the last sound heard in the word); ṣ, as in hiṣ; ch, as in chair. All consonants not marked have the same sound as in corresponding positions in ordinary English words.

Abyssinia, ăb-ĭs-ĭn′ĭạ
Aconcagua, ä-kŏn-kä′gwȧ
Adriatic, ăd-rĭ-ăt′ĭk
Afghanistan, ăf-ḡănˋĭs-tăn′
Aïnos, ä′ĭ-nōs
Aleutian, ȧ-lū′shĭạn
Aleuts, ȧ-lūts′
Algonquin, ăl-ḡŏn′kwĭn
Altai, ăl-tī′
Aluta, ä-lṳ′tä
Amargoza, ȧm-är-ḡō′zạ
Amargura, ȧm-är-ḡṳ′rä
Amazon, ăm′ạ-zọn
Amoo, ä′mōō
Amoor, ä-mōōr′
Andaman, ănˋdạ-măn′
Antilles, ăn-tēl *or* ăn-tĭl′lēs
Apache, ȧ-pä′che
Apennines, ăpˋẹn-nīnṣ′
Appalachian, ăpˋpạ-lā′chê-ạn
Apurimac, ä-pōōˋrê-măk′
Arab, ăr′ạb
Arafura, ä-rä-fṳ′rä
Aral, ăr′ạl
Ararat, ăr′ạ-răt
Araucanians, ȧ-rô-kä′nê-ạns
Araucaria, ȧ-rô-kȧ′rê-ạ
Ardennes, är-dĕn′
Arequipa, äˋrä-kē′pä
Arnhem, ärn′hĕm
Artois, är-tois′ *or* är-twä′
Ashantee, ȧ-shăn′tê
Atbara, ät-bä′rä
Athabasca, ăth-ạ-băs′kạ
Athabascans, ăth-ạ-băs′kạns
Aujila, ōd-jē′lȧ
Azores, ạ-zōreṣ′

Baer, bā′ĕr
Bahama, bạ-hä′mạ
Baikal, bī′käl
Balaton, bä′lạ-tŏñ
Balkan, bäl-kän′
Balkhash, bäl-käsh′
Bangweolo, băngˋwā-ō′lō
Barnaul, bärn-owl′
Bayonne, bä-yọn′
Bayou, bī′yōō
Bengal, bĕn-ga̤l′
Benue, bĕn′ụ-āˋ
Bergen, bẽr′ḡẹn
Bering, bēr′ĭng
Bermudas, bẽr-mū-dạṣ
Bhootan *or* Bhotan, bōō-tăn′
Bogota, bōˋḡō-tȧ′
Bolabola, bōˋlạ-bō′lạ
Bonin, bō-nēn′
Boorlos, bōōr′lōṣ
Boothia, bōō′thêä
Borneo, bôr′nê-ô
Botocudos, bōˋtō-cṳ′dōṣ
Bourbon, bōōr′bọn
Brahmapootra, bräˋmä-pōō′trä
Brazos, brä′zōs
Bretagne, brĕ-tăñ′
Bug, bōōḡ

Cabool, kä-bōōl′
Candahar, kăn-dạ-här′
Cañon, kăn′yọn
Cashmere, kăsh-mēr′
Casiquiare, käˋsē-kē-â′rä
Catamarca, kȧ-tȧ-mär′kȧ
Caucasians, kạ-kāṣ′ĭ-ạns
Caucasus, kạ′kạ-sŭs
Cavery, kä-vā′rĭ
Cayambe, kī-äm′bā
Celebes, sĕl′ê-bĕs
Celtic, sĕlt′ĭk
Cévennes, sā-vĕn′
Ceylon, sē′lọn
Chagos, chä′gōs
Chamalare, chăm-ạ-lä′rê
Charollais, shäˋrŏlˋlȧ′
Charybdis, kăr-ĭb′dĭs
Cherbourg, shĕr-bōōrḡ′
Cherraponjee, chērˋrạ-pọn′jê

Chili, chĭl′ê
Chilian, chĭl′ĭ-ạn
Chimborazo, chĭm-bō-rä′zô
Chippeways, chĭpˋpē-wāṣ′
Coimbra, kô-ĕm′brä
Colorado, kŏlˋô-rä′dô
Cossyah, kŏs′sê-ä
Costa Rica, kŏs′tä rē′kä
Côte d'Or, kōt′dôr′
Cotopaxi, kōˋtô-păx′ê
Crimea, krĭm-ē′ạ
Cuzco, kṳs′kō

Dakota, dȧ-kō′tạ
Dapsang, dăp-săng′
Deccan, dĕk′ạn
Dhawalagiri, dạ-wŏlˋạ-ḡēr′rê
Diamantina, dê-ä-măn-tē′nä
Dnieper, nē′pẹr
Dravida, drä-vē′dạ
Dyak, dī′ăk

Ecuador, ĕk-wä-dōr′
Eifel, ī′fẹl
Elburz *or* Elbourz, ĕl-bṳrz′
El Gran Chaco, ĕl grän chä′kô
Ellice, ĕl′ĭs
Erebus, ĕr′ê-bŭs
Erz, ĕrts
Esquimaux, ĕs′kê-mōṣ
Euphrates, ū-frā′tēs
Eyre, âr

Ferdinandia, fĕrˋdê-năn′dĭ-ȧ
Fichtel, fĭsh′tẹl
Forez, fō-rā′
Formosa, fôr-mō′sạ
Fuegians, fū-ē′jê-ạns
Fuego, fṳ-ā′ḡô

Gairdner, gârd′nẹr
Galapagos, ḡä-lạ-pä′ḡōs
Gallas, ḡäl′äṣ
Garonne, ḡä-rôn′
Gavarnie, ḡä-vär′nê
Geyser, ḡī′sẹr
Ghauts, ḡa̤ts
Gobi, ḡō′bê
Guaranis, ḡwä-rä′nēṣ
Guiana, ḡē-ä′nạ

Hamoon, hä-mōōn′
Hardt, härt
Harmattan, hạr-măt′tạn
Harz, härts
Hawaian, hä-wī′ạn
Hawaii *or* Hawai, hä-wī′ê
Hawash, hä′wäsh
Hayti, hā′tê
Haytian, hā′tê-ạn
Heath, hēth
Hellenic, hĕl-ĕn′ĭk
Helmund, hĕl′mŭnd
Henuake, hĕnˋụ-ä′kȧ
Hercynian, hẽr-sĭn′ê-ạn
Hielmar, hy-ĕl′mär
Himalaya, hĭm-ạ-lā′yạ
Hindoo Koosh, hĭn′dōō kōōsh′
Hoangho, hô-äng′hōˋ
Hogoleu, hō′gô-lṳ

Idaho, ī′dạ-hô
Iljamin, ĭl-yä′mĭn
Illimani, êl-yê-mä′nê
Irasu, ē-rä′sṳ
Irrawaddy, ĭr-ä-wŏd′ê
Ismailia, ĭs-mä′êl-yä

Jan Mayen, yän mī′ẹn
Jebel-Kibrit, jĕb-ĕl-kĭb′rĭt
Jolof, jŏl′ọf
Jorullo, hō-rōōl′yō

Kaffa, kăf′fä
Kaffre, kăf-fẹr
Kalmuks, kăl′mŭks
Kamchadale, kăm′chä-dālˋ

Kamchatka, kăm-chăt′kạ
Kamsin, kăm′sĭn
Karakorum, käˋrä-kō′rŭm
Keelfoss, kēl′fŏs
Kenai, kê-nä′ê
Kenia, kĕ′nê-ä
Kermadec, kẽrˋmạ-dĕk′
Khassia, kȧs′sê-ä
Khingan, kĭn-ḡän′
Kilauea, kēˋlō′â-ä
Kilima Njaro, kĭlˋê-mänˋjä-rō′
Kirghiz, kẽr′ḡēs
Kolushians, kô-lṳ′shê-ạnṣ
Koriaks, kō′rê-ăks
Kossogol, kŏs-ô-gŏl′
Kuenlun, kwĕn-lōōn′
Kurdistan, kōōrd-ĭs-tăn′
Kurile, kōō′rēl
Kuro Sivo, kṳ′rô sē′vô

Laccadive, lăk-ạ-dīv′
Lachlan, lăk′lạn
Ladoga, lăd′ō-gä *or* lạ-dō′gạ
Landes, läɴdz
Langres, läɴg′r
La Paz, lä päz
Lapponic, lăp′pô-nĭk
Leman, lāˋmäɴ′
Lena, lā-nä′ *or* lē′nạ
Levees, lĕv-ēṣ′
Limpopo, lĭm-pō′pô
Llano, l'yä′nô
Lofoden, lọ-fō′dẹn
Loire, l'wär′
Lucerne, lōō-sẽrn′
Lugano, lṳ-ḡä′nô

Maçon, mȧˋsôɴ′
Madeira, mạ-dē′rạ
Maelar, mā′lär
Maelstrom, māl′strŭm
Magdalena, măg-dạ-lē′nạ
Mageroe, mä′ḡẹ-rô
Maggiore, măd-jō′rä
Mahabuleshwur, mäˋhä-blĕsh-wŭr′
Maldive, măl-dīv′
Malgache, mălˋgăsh′
Malpays, măl-pā′ê
Manchoo, măn′chōō
Manchuria, măn-chōō′rê-ạ
Mandingo, măn-dĭng′ḡō
Mantiqueira, mănˋtē-kā′rä
Maori, mä′ô-rê
Maracaybo, *or* Maracaibo, mäˋrä-kī′bô
Marañon, mä-rän-yōn′
Maravaca, mäˋrä-vä′kä
Mareotis, mä-rȧ-ō′tēs
Margeride, mär-zhĕ-rēd′
Marianne, mäˋrê-än′
Maros, mär-ōsh′
Marquesas, mär-kā′săs
Mauna Kea, mạ-nạ kē′ạ
Mauna Loa, mạ-nạ lō′ạ
Maures, mōr
Mauritius, mạ-rĭsh′ê-ŭs
Mekong, mā-kông′
Melanesia, mĕlˋạ-nē′shĭ-ạ
Melrir, mĕl′rēr
Menzaleh, mĕn-zä′lĕ
Merapi, mā-rä′pē
Meuse, mūz
Micronesia, mĭcˋrô-nē′shĭ-ạ
Moero, mô-ā′rô
Molucca, mô-lŭk′ạ
Monte Somma, môn-tĕ sọm′mä
Muisca, mū-ĭs′kạ
Mur, mūr
Muxinga, mŭx-ĭng′ḡä

Narcondam, năr-cŏn′dăm
Natron, nā′trọn
Natupe, nä-tṳ′pā
Nevada, nā-vä′dạ
Nevado, nā-vä′dō
Newfoundland, nū′fŭnd-lăndˋ
Ngai, n'ḡä′ê
Ngami, n'ḡä′mê

Nicaragua, nĭc-ạ-rạ′ḡwạ
Nicobar, nĭc′ô-bärˋ
Nieuweveld, nyūw′vĕlt
Niger, nī′jẹr
Novaia Zemlia, nô-vī′ä zĕm′lē-ä
Nyanza, nī-ăn′zä
Nyassa, nī-äs′sä

Obi, ō′bê
Ofen, ō′fẹn
Ohiwao, ō-hê-wä′ô
Okhotsk, ō-kŏtsk′
Onega, ō-nē′gạ
Orizaba, ō-rê-zä′bä

Pamir, pä-mēr′
Pampa, păm′pä
Panama, păn-ạ-mä′
Papuan, păp′ōō-ạn
Paraguay, päˋrä-ḡwā′
Parana, päˋrä-nä′
Paumotu, powˋmō′tṳ
Peñas, păn′yȧs
Persian, pẽr′shĕ-ạn
Peschawer, pĕsh-ow′ẹr
Petchora, pĕch′ô-rä
Philippine, fĭl′ĭp-ĭn
Pic Anéthou, pēkˋä-nā′tōō
Pico de Teyde, pē′kô dẹ tī′dẹ
Pilcomayo, pĭlˋkô-mī′ô
Pitcairn, pĭt-kârn′
Polynesian, pŏlˋĭ-nē′shĭ-ạn
Popocatepetl, pô-pô-kătˋạ-pĕtl′
Porto Rico, pōr′tô rē′cô
Pruth, prōōth
Punta Parina, pōōn′tä pä-rē′nä
Purus, pōō′rōōs
Pyrenees, pĭr′ẹ-nēṣ

Quathlamba, kwät-läm′bä
Quechua, kwā-chṳ′ä
Quito, kē′tô

Radack, rä′däk
Rainier, rā′nēr
Ralick, rä′lĭk
Rauh, räṳ
Reisen, rē-ṣẹn
Reykjavik, rī-kĭ-ạ-vĭkˋ
Rhenish, rān′ĭsh
Rio Grande, rī′ô grȧnd
Rio Janeiro, rī′ô jân-ē′rô
Rilo Dagh, rē′lo däh′
Roumania, rōō-mā′nê-ạ

Samarang, săm-ạ-răng′
Samiel, sä′mĭ-ĕl
Samoa, sä-mō′ä
Samoiedes, să-moi′ēds
Sampu, săm′pōō
Santorini, săn-tô-rē′nê
Saône, sōn
Sarmiento, sär-mē-ĕn′tô
Saskatchewan, săs-kăch′ê-wạnˋ
Scandinavia, skănˋdĭ-nā′vĭ-ạ
Seathwaite, sēth′wāt
Seine, sān
Sereth, sĕr-ĕt′
Seychelles, sā-shĕl′
Shamo, shä′mô
Shasta, shȧs′tạ
Shoshonee, shô-shō′nê
Sidra, sĭd′rä
Sierra, sê-ĕr′rä
Siestan, sēs′tăn
Sikhota Alin, sê-kō′tä ä′lĕn
Simoon, sê-mōōn′
Sioux, sōōṣ
Sir Daria, sēr dä′rê-ä
Sir-i-kul, sērˋê-kŭl′
Siwa *or* Siwah, sē′vä
Sneeuw, snĕ-ōōv′
Socotora, sô-kō′trä
Somali, sô-mạ′lê
Sorata, sô-rä′tä
Staubbach, stäṳb′bäk

Soudan, sōō-dän′
Steppes, stĕps
Stromboli, strŏm-bō′lê
Suabo-Franconian, swā′bô-frănˋkô′nê-ạn
Suaheli, sṳˋä-hä′lê
Sudetic, sū-dĕt′ĭk
Sulitelma, sṳ-lĭ-tĕl′mä
Suliman, sṳ-lē-män′
Sunda, sŭn′dạ

Tahiti, tä-hē′tê
Taiara, tī-ä′rä
Tanganyika, tănˋgăn-yē′kä
Tanta, tăn′tä
Tapajos, tä-pä′zhōs
Tarawan, täˋrä-wan′
Tarim, tä′rêm
Ta Siue Shan, tä sēˋwā′shăn
Tchad, chăd
Tchukchees, chōōk′chēs
Tebu, tā′bṳ
Tengri Nor, tĕn′grê nôr
Tenuyan, tĕn-wē′ăn
Terai, tā-rä′ê
Tequendama, tāˋkwĕn-dä′m
Teutoburg, toi′tô-bōōrg
Theiss, tīs
Thian Shan, têˋän′ shăn
Thibet, tĭb-ẹt *or* tĭ-bĕt′
Thibetan, tĭb-ĕt′ạn
Thuringian, thṳ-rĭn′jê-ạn
Titicaca, tê-tê-kä′kä
Tocantins, tôˋkăn-tēnz′
Tolima, tō-lē′mä
Tolmezzo, tŏl-mĕt′zō
Transylvania, trănˋsĭl-vā′nĭ-ạ
Tristan da Cuñha, trĭs′tăn-dä-kṳn′yä
Tsien-tang, tsē-ĕn′tăng
Tuareg, tōō-ä-rĕḡ′
Tubuai, tṳ-bṳ′ī
Tufoa, tṳ-fō′ä
Tundra, tōōn′drạ
Tungusian, tōōn-gṳ′zhĭ-ạn
Tupis, tōō-pēṣ′
Tupungato, tṳ-pṳng-gä′tô
Turcoman, tōōrˋkō-măn′
Turkestan, tōōrˋkĕs-tăn′
Tzana, tză′nä

Ucayali, ōōˋkī-ä′lê
Ugrian, ōō′grê-ạn
Unalashka, ōōˋnä-lȧsh′kä
Ural, yu′rạl
Uruguay, yōō′rōō-ḡwā
Urumia, ōōˋrōō-mē′ä
Utah, yōō′tä

Valdai, väl′dī
Valdivia, välˋdē′vê-ä
Vermejo, vẽr-mā′hô
Vesuvius, vê-sōō′vê-ŭs
Vindhya, vĭnd′yä
Vistula, vĭs′tōō-lä
Volga, vŏl′gạ
Vosges, vōzh

Wahsatch, wä-säch′
Walachia, wä-lā′kê-ä
Waradin, wäˋrạs-dēn′
Wener, wā′nẹr
Weser, wē-zẹr
Wetteo, wĕt′ẹr

Xingu, shên-gōō′

Yablonoi, yä-blô-noi′
Yakutsk, yä-kōōts′k
Yangtse Kiang, yăngˋtsê kī-ăng′
Yanteles, yăn-tā′lĕṣ
Yapura, yä-pṳ′rä
Yenisei, yĕn-ê-sā′ê
Yosemite, yō-sĕm′ĭ-tĕ

Zambesi, zăm-bā′zê
Zermatt, zẽr-măt′

## TABLE OF MEAN TEMPERATURE AND RAINFALL IN THE UNITED STATES.

| NAMES OF PLACES. | POSITION OF STATIONS. | | | TEMPERATURE IN DEGREES FAHR. | | | Annual Rainfall in Eng. Inches. |
|---|---|---|---|---|---|---|---|
| EAST OF MISSISSIPPI RIVER. | North Latitude. | W. Long. of Greenwich. | Alt. in Eng. feet above ocean. | January. (Below zero —.) | July. | Year. | |
| Michipicoten, Lake Superior | 47° 56′ | 85° 6′ | 660 | 10.6 | 57. | 38.2 | 27.81 |
| Fort Kent, Me. | 47 15 | 68 35 | 575 | 11.1 | 62.5 | 37 | 36.45 |
| Mackinac, Mich. | 45 51 | 84 33 | 728 | 19.4 | 64.5 | 40.6 | 23.96 |
| Eastport, Me. | 44 54 | 66 59 | 40 | 22.4 | 62.3 | 43 | 40.09 |
| Fort Snelling, near St. Paul, Minn. | 44 53 | 93 10 | 820 | 13.7 | 73.4 | 44.6 | 25.82 |
| Potsdam, St. Lawrence Co., N.Y | 44 40 | 75 1 | 394 | 18.4 | 68.4 | 43.6 | 28.63 |
| Fort Howard, Wis. | 44 30 | 88 5 | 620 | 18.9 | 71.5 | 44.5 | 34.62 |
| Burlington, Vt. | 44 28 | 73 11 | 346 | 20.5 | 69.9 | 45 | 34.15 |
| Sackett's Harbor, N.Y. | 43 55 | 75 57 | 266 | – | – | 45.1 | 36.73 |
| Hanover, Dartmouth College, N.H. | 43 42 | 72 17 | 530 | ’ .8 | 64.4 | 40 | 40.32 |
| Portland, Me. | 43 38 | 70 15 | 20 | 22.8 | 68.2 | 45.2 | 43.63 |
| Concord, N.H. | 43 12 | 71 29 | 374 | 21.2 | 67.1 | 44.5 | 40.99 |
| Rochester, N.Y. | 43 8 | 77 51 | 500 | 26.9 | 69.9 | 47 | 32.56 |
| Prairie du Chien, Wis. | 43 5 | 91 | 642 | 19.4 | 75.3 | 47.6 | 35 |
| Portsmouth, N.H. | 43 5 | 70 46 | 50 | 24.9 | 67.1 | 45.8 | 29.88 |
| Milwaukee, Wis. | 43 3 | 87 55 | 591 | 25.2 | 69.8 | 46.4 | 30.40 |
| Buffalo, N.Y. | 42 53 | 78 55 | 600 | – | – | 46.1 | 33.84 |
| Albany, N.Y. | 42 39 | 73 45 | 75 | 24.3 | 72.1 | 48.2 | 40.52 |
| Amherst College, Mass. | 42 22 | 72 34 | 267 | 23.7 | 71 | 46.7 | 43.90 |
| Boston, Mass. | 42 22 | 71 4 | 50 | 27.8 | 71.6 | 48.9 | 39.40 |
| Detroit, Mich. | 42 20 | 83 | 562 | 27 | 69.7 | 47.2 | 30.05 |
| Chicago, Ill. | 41 54 | 87 38 | 591 | 23.6 | 70.8 | 46.7 | 33 |
| Providence, R.I. | 41 50 | 71 23 | 150 | 27.5 | 70.6 | 47.9 | 41.38 |
| Cleveland, O. | 41 42 | 81 36 | 625 | – | – | 48.9 | 37.61 |
| Fort Armstrong, Rock Island, Ill. | 41 30 | 90 40 | 528 | 22.8 | 76.5 | 50.3 | 38 |
| West Point, N.Y. | 41 24 | 73 57 | 167 | 28.3 | 73.7 | 50.7 | 47.65 |
| New Haven, Conn. | 41 18 | 72 55 | 50 | – | – | 50.8 | 44.43 |
| Nantucket, Mass. | 41 17 | 70 6 | 80 | 34.9 | 71 | 50.4 | 41.10 |
| Logansport, Ind. | 40 4 | 86 1 | 625 | 15.1 | 72.9 | 50.9 | 37.34 |
| New York, N.Y. | 40 42 | 74 1 | 23 | 30.2 | 74.8 | 51.7 | 44.59 |
| Pittsburg, Penn. | 40 27 | 79 59 | 850 | 29.1 | 73 | 50.8 | 47.68 |
| Philadelphia, Girard College, Penn. | 39 58 | 75 10 | 133 | 32.1 | 74.7 | 52.7 | 35.55 |
| Marietta, O. | 39 25 | 81 31 | 630 | 32.6 | 73.5 | 52.6 | 42.55 |
| Baltimore, Md. | 39 18 | 76 36 | 30 | 30.9 | 75.2 | 53.1 | 40.84 |
| Cincinnati, O. | 39 6 | 84 28 | 582 | 30 | 74.5 | 53.8 | 44.87 |
| Washington, D.C. | 38 53 | 77 1 | 40 | 28.3 | 76.7 | 55.1 | 41.05 |
| Fort Washington, Md. | 38 43 | 77 2 | 60 | 35.5 | 80 | 57.8 | 45.02 |
| Louisville, Ky. | 38 10 | 85 40 | 450 | 35.8 | 74.6 | 54.9 | 48.12 |
| Richmond, Va. | 37 32 | 77 27 | 172 | 33.7 | 77.6 | 56.2 | 38.29 |
| Fortress Monroe, Va. | 37 | 76 18 | 8 | 36.5 | 78.2 | 59.9 | 47.04 |
| Nashville, Tenn. | 36 10 | 86 49 | 533 | 38.2 | 79.5 | 58.5 | 52.02 |
| Knoxville, Tenn. | 35 59 | 83 54 | 1,000 | 30.5 | 74.1 | 55.7 | 39.76 |
| Chapel Hill, N.C. | 35 54 | 79 17 | 570 | 41.5 | 78.2 | 59.7 | 42.71 |
| Memphis, Tenn. | 35 8 | 90 | 262 | 41.7 | 79.9 | 60.8 | 45.46 |
| Huntsville, Ala. | 34 43 | 86 46 | 600 | 42 | 76.4 | 59.1 | 54.88 |
| Columbia, S.C. | 33 55 | 81 2 | 315 | – | – | 57.1 | 47.17 |
| Smithville, Fort Johnston, N.C. | 33 55 | 78 1 | 20 | 49 | 81.5 | 65.7 | 46.01 |
| Augusta, Ga. | 33 28 | 81 58 | 600 | 46.7 | 81.9 | 64 | 24.20 |
| Charleston, S.C. | 32 47 | 79 56 | 25 | 48.1 | 80.1 | 65.9 | 41.92 |
| Savannah, Ga. | 32 5 | 81 5 | 42 | 54.4 | 81.4 | 67.4 | 48.32 |
| Natchez, Miss. | 31 34 | 91 28 | 264 | 52.3 | 81.3 | 67.1 | 53.55 |
| Mobile, Ala. | 30 41 | 88 2 | 30 | 57.6 | 83.7 | 70.3 | 64.42 |
| Bâton Rouge, La. | 30 26 | 91 18 | 41 | 53.5 | 81.8 | 68.1 | 60.16 |
| Pensacola, Fla. | 30 24 | 87 13 | 18 | 53.6 | 82.3 | 68.7 | 59.27 |
| New Orleans, La. | 29 57 | 90 4 | 20 | 55.3 | 82.9 | 69.9 | 51.05 |
| St. Augustine, Fla. | 29 54 | 81 19 | 8 | 57 | 80.9 | 69.6 | 43.16 |
| Cedar Keys, Fla. | 29 7 | 83 3 | 35 | 55.6 | 81.3 | 70.5 | 45.77 |
| Tampa Bay, Fla. | 28 | 82 28 | 20 | 61.5 | 80.7 | 71.9 | 51 |
| Fort Dallas, Fla. | 25 55 | 80 20 | 20 | 66.4 | 82.1 | 74.7 | 59.04 |
| Key West, Fla. | 24 34 | 81 48 | 10 | 69.5 | 82.5 | 76.4 | 36.23 |
| WEST OF MISSISSIPPI RIVER. | | | | | | | |
| Point Barrow, Alaska | 71 21 | 156 17 | – | –18.5 | 36.1 | 7.1 | – |
| Fort Yukon, Alaska | 66 | 147 | – | –26.6 | 65.7 | 16.8 | – |
| Sitka, Alaska | 57 3 | 135 18 | – | 32 | 55.5 | 43.2 | 83 |
| Pembina, Dak. | 49 | 97 | 700 | – | 74.4 | – | 15 |
| Fort Union, Dak. | 48 | 104 | 2,022 | 21.3 | 73.6 | – | 11 |
| Fort Benton, Mont. | 47 50 | 110 36 | 2,663 | 16.5 | 73.6 | 48.2 | 12.50 |
| Steilacoom, W.T. | 47 10 | 122 25 | 300 | 38.7 | 64.2 | 50.8 | 43.98 |
| Astoria, Or. | 46 11 | 123 49 | 50 | 43 | 61.6 | 52.2 | 86.35 |
| Fort Pierre, Dak. | 44 23 | 100 12 | 1,456 | 19.2 | 76.9 | 51.9 | 13.51 |
| Fort Orford, Or. | 42 44 | 124 29 | 50 | 48.4 | 59.7 | 53.6 | 70.59 |
| Dubuque, Iowa | 42 30 | 90 40 | 666 | 19.8 | 75.2 | 49.4 | 33.47 |
| Fort Dodge (Clarke), Iowa | 42 28 | 94 3 | 880 | 19.6 | 76.2 | 47.4 | 26.82 |
| Fort Laramie, Wyo. | 42 12 | 104 31 | 4,519 | 31 | 74.7 | 50.1 | 15.16 |
| Des Moines, Iowa | 41 35 | 93 37 | 830 | 27.4 | 76.5 | 49.7 | 23.94 |
| Council Bluffs, Iowa | 41 30 | 95 48 | 1,250 | 19.4 | 75.9 | 49.3 | 29 |
| Salt Lake City, Utah | 40 46 | 112 6 | 4,320 | 27.1 | 81.5 | – | 28.85 |
| Fort Kearney, Neb. | 40 38 | 98 57 | 2,360 | 21.1 | 73.5 | 47.7 | 25.25 |
| Fort Reading, Cal. | 40 30 | 122 5 | 674 | 44.2 | 82.9 | 62.1 | 29.11 |
| Denver, Col. | 39 44 | 104 57 | 5,000 | 32 | 78 | 48 | 16 |
| Fort Leavenworth, Kan. | 39 21 | 94 48 | 896 | 28 | 76.7 | 52.8 | 31.74 |
| Fort Riley, Kan. | 39 3 | 96 35 | 1,300 | 27.1 | 83.7 | 56.6 | 23.62 |
| St. Louis, Mo. | 38 37 | 90 16 | 481 | 31.4 | 78.2 | 54.5 | 42.48 |
| Sacramento, Cal. | 38 34 | 121 28 | 82 | 45.3 | 73.9 | 59.9 | 19.59 |
| San Francisco, Cal. | 37 48 | 122 27 | 130 | 49.6 | 57.9 | 54.9 | 23.50 |
| Fort Atkinson, Kan. | 37 47 | 160 14 | 2,330 | 33.4 | 79.2 | 54.6 | 23 |
| Fort Scott, Kan. | 37 45 | 94 45 | 1,000 | 32.9 | 77.2 | 54.5 | 42.15 |
| Fort Massachusetts, Col. | 37 32 | 105 23 | 8,365 | 19.7 | 63.5 | 41.1 | 17.06 |
| Fort Miller, Cal. | 37 | 119 40 | 402 | 47 | 90.2 | 66 | 18.99 |
| Monterey, Cal. | 36 36 | 121 52 | 140 | 52.2 | 58.5 | 55.3 | 12.20 |
| Santa Fé, N.M. | 35 41 | 106 2 | 6,846 | 31.4 | 72.6 | 50.6 | 17 |
| Little Rock, Ark. | 34 42 | 92 15 | 150 | 40 | 80 | 62.3 | 47 |
| Fort Washita, Ind. T. | 34 14 | 96 38 | 645 | 42.9 | 80.7 | 62.2 | 38.04 |
| Los Angeles, Cal. | 34 3 | 118 12 | 457 | 52.8 | 75 | 62 | 13 |
| Fort Belknap, Tex. | 33 8 | 98 40 | 1,600 | 42.8 | 82.3 | 64 | 28.05 |
| Fort Webster, N.M. | 32 48 | 108 5 | 6,350 | 40.6 | 75.1 | 54.8 | 19.46 |
| Fort Yuma, Cal. | 32 44 | 114 36 | 200 | 56.4 | 92.3 | 73.6 | 3.46 |
| San Diego, Cal. | 32 42 | 117 14 | 150 | 51.9 | 72.7 | 62 | 9.16 |
| Fort Fillmore, N.M. | 32 14 | 106 15 | 3,937 | 44.5 | 83.4 | 64 | 8.42 |
| Fort Graham, Tex. | 31 56 | 97 26 | 900 | 47.9 | 83.1 | 65.7 | 40.58 |
| Natchitoches, La. | 31 33 | 93 32 | 100 | 50.6 | 82.2 | 66.3 | 54 |
| Austin, Tex. | 30 15 | 97 47 | 200 | 46.4 | 80.7 | 66.7 | 30.50 |
| Galveston, Tex. | 29 19 | 94 47 | – | 48.1 | 83 | 69.4 | 42 |
| Fort Clark, Tex. | 29 17 | 100 25 | 1,000 | 47.2 | 81 | 67 | 22.38 |
| Brownsville, Tex. | 25 54 | 97 26 | 50 | 60.4 | 84.2 | 73.7 | 37 |

## TABLE OF MEAN TEMPERATURE AND RAINFALL IN THE WORLD.

| NAMES OF PLACES. | POSITION OF STATIONS. | | | TEMPERATURE IN DEGREES FAHR. | | | Annual Rainfall in Eng. Inches. |
|---|---|---|---|---|---|---|---|
| EUROPE. | Latitude. (South –.) | Long. from Greenwich. (West –.) | Alt. in Eng. feet above ocean. | January. (Below zero —.) | July. | Year. | |
| Hammerfest, Norway | 70° 40′ | 23° 46′ | – | 22.5 | 53.2 | 35.5 | – |
| Archangel, Russia | 64 33 | 40 34 | – | 7 | 61.5 | 33.5 | – |
| Reykjavik, Iceland | 64 8 | –21 55 | 38 | 30 | 56.2 | 39.4 | 31 |
| Bergen, Norway | 60 24 | 5 18 | – | 35 | 60.4 | 46.8 | 88 |
| St. Petersburg, Russia | 59 57 | 30 18 | – | 15.5 | 62.5 | 38.8 | 18 |
| Christiania, Norway | 59 55 | 10 43 | 79 | 21.31 | 61 | 41.1 | 21 |
| Ekaterinburg, Russia | 56 50 | 60 34 | 852 | 2.3 | 63.8 | 33.2 | 13 |
| Edinburg, Scotland | 55 58 | 3 11 | 354 | 37.4 | 58.5 | 47.1 | 19 |
| Moscow, Russia | 55 45 | 37 34 | 490 | 11.9 | 67.8 | 40.4 | 21 |
| Bremen, German Empire | 53 5 | 8 49 | 19 | 29.6 | 64.6 | 48.1 | 24 |
| Dublin, Ireland | 52 21 | 6 15 | 19 | 40.4 | 58.2 | 48.4 | 29 |
| Berlin, Prussia | 52 30 | 13 3 | 153 | 28.1 | 66.2 | 48.2 | 23 |
| Warsaw, Poland | 52 13 | 21 1 | 325 | 21.5 | 64.3 | 44.3 | 23 |
| London, England | 51 30 | – 5 | – | 37.4 | 64.1 | 50.8 | 19 |
| Brussels, Belgium | 50 51 | 4 22 | 193 | 36 | 64.8 | 50.3 | 29 |
| Paris, France | 48 50 | 2 20 | 121 | 35.4 | 65.6 | 51.3 | 23 |
| Vienna, Austria | 48 12 | 16 22 | 637 | 28.9 | 69.5 | 50.2 | 18 |
| Odessa, Russia | 46 25 | 30 44 | 157 | 26.1 | 71.5 | 49.2 | 14 |
| Astrakhan, Russia | 46 21 | 48 5 | –36 | 19.9 | 77.9 | 49.2 | 5 |
| Lyon, France | 45 45 | 4 49 | 936 | 36.3 | 70.6 | 52.4 | 31 |
| Milan, Lombardy, Italy | 45 28 | 9 21 | 392 | 33.3 | 74.5 | 54.6 | 38 |
| Bordeaux, France | 44 51 | – 34 | 42 | 42.4 | 69.1 | 55.1 | 26 |
| Belgrade, Turkey | 44 50 | 20 25 | 266 | 33.3 | 76.6 | 54.2 | 26 |
| Florence, Italy | 43 47 | 11 15 | 234 | 40.8 | 76.3 | 57 | 35 |
| Constantinople, Turkey | 41 7 | 28 59 | 160 | 40.4 | 74.1 | 57.6 | 29 |
| Madrid, Spain | 40 25 | – 3 41 | 1,327 | 44.7 | 76.3 | 58 | 18 |
| Lisbon, Portugal | 38 43 | – 9 8 | 321 | 48.6 | 69.8 | 59.5 | 27 |
| Naples, Italy | 38 11 | 15 34 | 222 | 46.8 | 75.4 | 59.9 | 31 |
| Athens, Greece | 37 58 | 23 50 | 393 | 45.5 | 79.5 | 62.4 | 10 |
| AFRICA. | | | | | | | |
| Algiers, Algeria | 36 47 | 3 5 | 65 | 50.1 | 80.4 | 69.1 | 36 |
| Funchal, Madeira | 32 38 | –16 56 | 85 | 63.5 | 72.5 | 67.6 | 28 |
| Cairo, Egypt | 30 2 | 31 15 | – | 56.3 | 85.6 | 71.3 | – |
| Kuka, Bornu | 13 10 | 14 30 | – | 75.7 | 83.6 | 83.3 | 33 |
| Christiansborg, Guinea | 5 24 | 10 | – | 81.1 | 77.1 | 80.4 | 144 |
| Gondokoro | 4 44 | 31 40 | – | 89.4 | 78.4 | 83.1 | – |
| Zanzibar | – 6 28 | 39 30 | – | 83.3 | 77.1 | – | 107 |
| St. Helena | –15 55 | – 5 43 | 1,760 | 64 | 58 | 61.4 | 48 |
| Port D'Urban, Natal | –29 40 | 31 | – | 76.2 | 59 | 67.8 | – |
| Cape Town, Cape Colony | –33 56 | 18 29 | – | 67.6 | 54.4 | 60.7 | 19 |
| ASIA. | | | | | | | |
| Ust Yansk, Siberia | 70 55 | 138 24 | – | –38.5 | 52.6 | 2.8 | – |
| Yakutsk, " | 62 2 | 129 45 | 299 | –41.3 | 63.2 | 12.4 | 9 |
| Okhotsk, " | 59 21 | 143 11 | 13 | –11.6 | 54.6 | 23.1 | – |
| Tobolsk, " | 58 2 | 88 16 | 378 | – 2.9 | 63.4 | 33 | 18 |
| Barnaul, " | 53 20 | 103 27 | 300 | – 4.4 | 67.5 | 32.3 | 9 |
| Petropaulovski, Kamchatka | 53 | 158 42 | – | 20.3 | 58.1 | 37 | – |
| Irkutsk, Siberia | 52 17 | 104 11 | 1,270 | – 6.5 | 64.9 | 30.7 | – |
| Tiflis | 41 41 | 44 50 | 1,487 | 32.4 | 75.6 | 55 | 19 |
| Peking, China | 39 54 | 116 26 | – | 25.8 | 79.9 | 54.6 | 24 |
| Baghdad, Asiatic Turkey | 33 21 | 44 22 | – | 48.6 | 93.2 | 73.6 | 6 |
| Nagasaki, Kiusiu, Japan | 32 45 | 129 52 | 28 | 42.3 | 79.3 | 61 | – |
| Jerusalem, Syria | 31 47 | 35 14 | 2,610 | 46.7 | 76.4 | 63.6 | – |
| Canton, China | 23 8 | 113 16 | – | 52.5 | 83 | 69.9 | 78 |
| Calcutta, India | 22 38 | 88 20 | 83 | 71.7 | 84.2 | 81.1 | 68 |
| Bombay, Deccan | 18 56 | 72 54 | – | 73.3 | 80.7 | 79.8 | 84 |
| Manila, Philippine Islands | 14 36 | 129 | – | 77.1 | 80.3 | 79.5 | – |
| Bangkok, Siam | 13 40 | 10 1 | – | 76.7 | 82 | 81.1 | – |
| Aden, Yemen | 12 46 | 45 15 | 199 | 72.6 | 83.4 | 80.2 | – |
| Trivandrum, Deccan | 8 31 | 77 | – | 78 | 78 | 79.2 | 69 |
| Kandy, Ceylon | 7 17 | 80 49 | 1,790 | 70.6 | 72.5 | 72.7 | 82 |
| Singapore | 1 17 | 103 50 | – | 78.4 | 82.2 | 80.7 | 90 |
| Amboyna, Molucca Islands | – 3 41 | 128 15 | – | 80.5 | 77 | 79.1 | – |
| Batavia | – 6 9 | 106 53 | – | 78.7 | 78 | 78.8 | 149 |
| POLYNESIA AND AUSTRALIA. | | | | | | | |
| Honolulu, Sandwich Islands | 21 16 | –157 59 | – | 71.7 | 78.9 | 75.4 | 22 |
| Raiatea, Society Islands | –16 40 | –160 | – | 78.7 | 75.7 | 78.4 | – |
| Freemantle, West Australia | –32 15 | 116 30 | – | 70.8 | 57 | 62.7 | 35 |
| Sydney, New South Wales | –33 40 | 151 | – | 71.7 | 49.8 | 61.3 | 83 |
| Adelaide, South Australia | –34 35 | 138 45 | – | 84.4 | 54.2 | 68.4 | 22 |
| Auckland, New Zealand | –36 50 | 174 51 | – | 67.9 | 49 | 58.6 | 48 |
| Wellington, New Zealand | –41 16 | 174 47 | – | 66.4 | 48.7 | 58.3 | – |
| NORTH AMERICA. | | | | | | | |
| Upernavik, Greenland | 72 48 | –55 40 | – | –12.3 | 38.5 | 12 | – |
| Fort Simpson, British N. America | 61 51 | –120 25 | 300 | –12.5 | 61 | 25.7 | – |
| Assiniboine, Manitoba | 50 | –97 8 | 639 | – 2.9 | 69.6 | 35.3 | – |
| St. John's, Newfoundland | 47 37 | –52 43 | – | 23.4 | 56 | 38.3 | 63 |
| Montreal, Pr. Quebec | 45 50 | –77 52 | 266 | 15 | 73.2 | 44.6 | 42 |
| Windsor, Nova Scotia | 44 59 | –64 7 | 213 | 25.1 | 63.5 | 41.9 | 29 |
| St. George, Bermudas | 32 23 | –64 50 | – | 65.7 | 82.4 | 72.7 | 59 |
| Matamoras, Mexico | 25 52 | –97 27 | 55 | 60.4 | 84.2 | 73.6 | 37 |
| Havana, Cuba | 23 9 | –82 13 | – | 71.4 | 81.4 | 77.1 | 40 |
| Mexico, Mexico | 19 30 | –99 1 | 7,450 | 52.5 | 65.3 | 60.7 | – |
| Vera Cruz, Mexico | 19 12 | –96 9 | – | 71 | 81.5 | 77.7 | 183 |
| St. Thomas, West Indies | 18 21 | –64 56 | – | 80.8 | 82.7 | 82.3 | 35 |
| Balize, British Honduras | 17 29 | –88 73 | – | 75 | 82 | 79.5 | 72 |
| Guatemala, Central America | 14 40 | –90 28 | 4,960 | 65 | 68.9 | 67.8 | 55 |
| SOUTH AMERICA. | | | | | | | |
| Maracaibo, Venezuela | 10 43 | –71 52 | – | 81.3 | 86.6 | 84.7 | – |
| Georgetown, British Guiana | 6 49 | –58 12 | – | 78.4 | 79 | 79.5 | 100 |
| Bogota, United States of Columbia | 4 36 | –74 14 | 8,600 | 57 | 56.2 | 57.7 | 74 |
| Quito, Ecuador | – 0 14 | –78 46 | 9,543 | 58.2 | 59.1 | 60.1 | – |
| Para, Brazil | – 1 28 | –48 29 | – | 80.1 | 81.5 | 80.6 | 71 |
| Lima, Peru | –12 3 | –77 8 | 564 | 78.1 | 68.5 | 73.3 | – |
| Rio Janeiro, Brazil | –22 24 | –43 16 | – | 79.6 | 70.6 | 75.2 | 53 |
| Asuncion, Paraguay | –25 16 | –57 41 | 262 | 36.5 | 65.1 | 74.3 | – |
| Valparaiso, Chili | –33 2 | –76 24 | – | 66 | 57.3 | 60.6 | – |
| Montevideo, Uruguay | –34 54 | –56 13 | 32 | 73 | 51.8 | 62.1 | 43 |
| Falkland Islands | –52 | –61 | – | 56 | 37.4 | 47.2 | – |

**NOTE.**— The *altitudes* given above refer to the position of the instruments used in observation.